

# solas news

Issue 15 : Summer 2013 : [www.solas-int.org](http://www.solas-int.org)



▲ **Photo:** Aerial view of the fjord of Kiel, Germany where the west shore building of GEOMAR Helmholtz Centre for Ocean Research Kiel is hosting the International Project Office of SOLAS. Pencil in your calendar to visit Kiel in September 2015 to attend the next SOLAS Open Science Conference. For more information see the back cover. Photo credit: A. Villwock - GEOMAR

## SOLAS Newsletter issue 15

This issue of the SOLAS Newsletter serves as a general update of what has kept part of the SOLAS scientific community busy over the last year. We hope you will find the following articles and reports on recent achievements in the air-sea science, in particular with regards to the SOLAS Mid-Term Strategy topics, informative. For example in the framework of the SOLAS/IGAC Halogens in the Troposphere task team (HitT), a workshop was held in Kiel, Germany on the climate impact of seasalt-derived Cl atoms. Outcomes of this event are reported in this issue, and to illustrate the progress of HitT, a scientific contribution is also featured.

You will also find a scientific contribution related to the science of the SOLAS focus 2 on processes of air-sea exchange, accompanied by some updates about the collaboration between SOLAS and the European Space Agency (ESA).

The science of the SOLAS/IMBER Carbon group has not been forgotten. Scientific contributions are illustrating the progresses made by the three sub-groups. An update on the Surface Ocean CO<sub>2</sub> Atlas (SOCAT) and an article introducing the Ocean Acidification International Coordination Centre (OA-ICC) are also included.

As in every issue, we also attempt to bring you an update of the activities in nations where SOLAS has a strong presence and progresses are being made, along with information and activities about other international projects which might be of interest to the SOLAS community.

We invite you to subscribe to our mailing list to receive our e-bulletins and future newsletters, visit: <http://www.solas-int.org/community/join.html>

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# SOLAS Mid-Term Strategy

To have a good overview of the science behind the five topics of the Mid-term Strategy, SOLAS invites you to read the paper published in Environmental Chemistry earlier this year by Law and co-authors entitled 'Evolving Research Directions in Surface Ocean-Lower Atmosphere (SOLAS) Science'.

During the last year, the SOLAS Mid-Term Strategy (MTS) topics kept on evolving.

Contributing to the MTS on 'Ocean-derived aerosols: production, evolution and impacts', a workshop was held in December 2012 in Kiel, Germany regarding the effects of marine gels on clouds, a short report is included in this issue. Also, a new SCOR Working Group (WG 141) was created in order to increase the awareness of the sea-surface microlayer. The leaders described their goals for the SOLAS community in the comprised report. Two relevant scientific contributions are being published in this

newsletter, one regarding the link between coccolithophore species and aerosol fluxes to the lower atmosphere and a second one, regarding natural surfactants of the sea surface films. The SOLAS Scientific Steering Committee (SSC) also welcomes a new member, Ilan Koren from Israel, whose research interest on clouds will complement the SOLAS SSC expertise for this MTS and beyond. An update of the international project IGAC and its recent activities is also included.

Contributing of the MTS on 'Atmospheric control of nutrient cycling and production in the surface ocean', a scientific article on the effects of ocean acidification on iron availability to marine phytoplankton is included in this issue. In addition, a review paper by Moore et al. published in Nature Geoscience is advertised. This paper is an outcome of the IGBP/SCOR Fast

Track Initiative on 'Upper Ocean Nutrient Limitation: processes, patterns and potential changes'.

Contributing to the 'Sea-ice biogeochemistry and interaction with the atmosphere' MTS topic, an update of BEPSII, the SCOR Working Group WG 140 focusing on the biogeochemical exchange processes at sea ice interfaces is presented. A scientific contribution on an approach to modelling sea ice biogeochemistry from local to Earth System scales is also featured.

Contributing to the MTS topic on 'Air-sea gas fluxes at Eastern boundary upwelling and Oxygen Minimum Zone (OMZ) Systems', a workshop was organized entitled "Towards an integrative regional coupling in the Eastern Boundary Upwelling Systems" in November 2012 in Lima, Peru. On page 13, you can read about it, accompanied by a scientific contribution.

## Workshop on 'Marine gels effects on clouds'

11-13 December 2012  
Kiel, Germany

Recent incongruence found on the CLAW hypothesis stressed the importance of the role of polymer gels in marine environments. Marine and atmospheric scientific communities use to have individual unique perspectives, tools and data on that topic. The increased research interest has brought these two communities to meet and discuss together.

To support the scientific community, SOLAS and IGAC co-sponsored 13 international well established scientists from a wide range of disciplines to combine their knowledge in order to summarize the current state of knowledge of polymer gels in the ocean and atmosphere. The participants hoped to develop a common vocabulary to be used by all the represented disciplines including atmospheric chemistry and physics, marine microbiology and chemistry, meteorology and cloud microphysics. Finally they articulated a research agenda for future progress in understanding the production, emissions and possible climate impact of these intriguing biomaterials.



The following issues and controversies were the central discussion topics:

Is the "gel theory of marine cloud condensation nuclei (CCN)" origin consistent with primary marine aerosol observations and is it coupled to the sulfur cycle? Does CCN activation of gels occur? What physical/chemical processes are involved? Is "downsizing" of atmospheric gel particles possible? Does the composition/abundance of marine

surface-active gels vary spatially/temporally? Do variations in ocean biology influence variability of the primary organic aerosol? What are the connections between marine gel emissions and future environmental change: polar, costal and open ocean?

For more information about the workshop please visit our website: [www.solas-int.org](http://www.solas-int.org) or contact the workshop conveners Caroline Leck ([lina@misu.su.se](mailto:lina@misu.su.se)) and Eric Saltzman ([esaltzma@uci.edu](mailto:esaltzma@uci.edu)).



# Introduction to the newly created SCOR Working Group on sea surface microlayer

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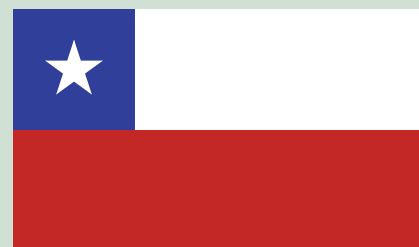
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The sea-surface microlayer (SML) is the boundary interface between the atmosphere and ocean, covering about 70% of the Earth's surface. The SML has physico-chemical and biological properties that are measurably distinct from underlying waters. Because of its unique position at the air-sea interface, the SML is central to a range of global biogeochemical and climate-related processes.

The new SCOR working group WG 141 is dedicated to increase the awareness of the science community to the importance of the SML in a wide range of biogeochemical and climate-related processes. The SCOR WG 141 will use a multidisciplinary perspective to suggest the future direction of SML research at an international level. The group will bring scientists from various disciplines together to consider chemical, biological and physical aspects of the SML,

and to understand governing mechanisms in its formation and role in biogeochemical cycling and climate science.

Members of the group met for the first time during the European Geosciences Union General Assembly in Vienna in April 2013, and discussed the latest advances in microlayer research, including; best practices in the sampling of the SML, an updated consensus on the SML, and the SML's role in a changing ocean. The group is organizing a 4-day workshop in 2014 planned to be held in China (Qingdao Ocean University). The workshop includes training students in SML sampling techniques and promoting SML research to the next generation of oceanographers. The group will also organize a special session on the SML at a major international ocean science meeting in 2015 or 2016.



## SOLAS Chile

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The Chilean Commission for Science and Technology established the Center for Climate and Resilience Research at the University of Chile; it aims to become a world-class research center focusing on Earth System Science. The proposed research will focus particularly in processes cycling greenhouse gases in surface waters. This center will also increase the outreach and capacity to allow new post-doctoral positions and new scholarships for students.

The year 2012 marked the 10th anniversary of the Center for Oceanographic Research in the South Eastern Pacific. The center has been running a time series study off central-south Chile (36° S). This study reflects an integrated, ongoing activity of the center through which all the individual research programs converge into a unique platform to tackle scientific questions. It has registered 10 years of measurements of greenhouse gases (N<sub>2</sub>O and CH<sub>4</sub>).

Scientific highlight: Following the N<sub>2</sub>O consumption at the Oxygen Minimum Zone in the eastern South Pacific

Cornejo and Farías tackled the open question about how to look at the global balance between N gains and losses in the ocean and earth system. Relationships were used depending on threshold levels of oxygen and nitrite to reproduce the apparent N<sub>2</sub>O production. They showed evidence that oceanic N<sub>2</sub>O may be higher than previously thought. The results will improve the prediction of N<sub>2</sub>O behavior under future Oxygen Minimum Zones expansion scenarios.

Cornejo, M., Farías, L. (2012). Following the N<sub>2</sub>O consumption at the Oxygen Minimum Zone in the eastern South Pacific. *Biogeosciences* 9, 3205-3212. Doi10.5194/bg-9-3205-2012



## New SOLAS Scientific Steering Committee member

We welcome newly appointed SSC member Ilan Koren who joined the SOLAS SSC in January 2013.

Ilan Koren studies clouds and rain and their link to processes in the ocean. He completed his PhD in atmospheric physics at Tel Aviv University in 2002 and then moved to the USA to conduct a postdoctoral

research at NASA-Goddard Space Flight Center, focusing on problems related to cloud aerosol interactions. Since 2006 he works at the Weizmann Institute in Israel expanding his interest to questions related to self-organization of marine-clouds, systems approach and the link between algae bloom dynamics and sea-air fluxes.



Sanja Milosavljevic is research associate at Ruđer Bošković Institute, Zagreb, Croatia. She obtained her PhD in Oceanography working on development of complex methodological approach to the physico-chemical characterization of the sea surface microlayer. Her research interests also include physico-chemical characterization of organic matter in aquatic systems and atmospheric aerosols.

## Natural surfactants of the sea surface films from the coastal Middle Adriatic area

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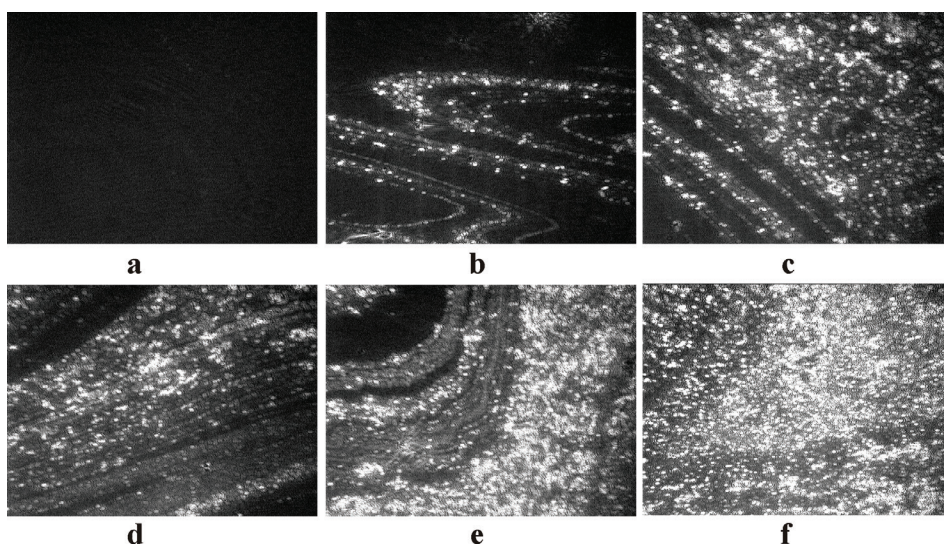
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The sea surface microlayer (SML) as a top layer of the ocean surface represents a natural interface between the atmosphere and the ocean. Although <1 mm in thickness, the SML is central to a range of global dynamic exchange processes between the atmosphere and the aquatic environments where a striking variety of biogeochemical and photochemical interactions and feedbacks occur (Liss and Duce, 1997). A large fraction of the SML organic matter has a particularly strong interfacial affinity. Due to their molecular structures, such surface active substances (SAS) are adsorbed at the air-water interface forming natural surface films which change the physicochemical properties of the interface and influence the air-sea exchange processes. The biota of the underlying water column is the primary source of organic material since the phytoplankton exudates are assumed to be one of the largest SAS sources. Marine phytoplankton excretion products include polymeric macromolecules which are frequently found in surface waters during phytoplankton blooms. Lipids are also present in phytoplankton exudates but they are generally less abundant than carbohydrates and proteins. However, their contribution to the SML properties may be disproportionally large. It is known that lipids significantly influence the viscoelastic properties of microlayers (Frew and Nelson, 1992), having thus a large potential to impact the air-sea exchange processes.

A new perspective to the physicochemical characterization of the SML properties regarding the composition and the structure of dominant surface active material has been recently studied on the SMLs from the coastal Middle Adriatic locations, including the seawater Rogoznica Lake and Martinska station situated at the Krka river estuary (Frka et al., 2009; Frka et al., 2012). Natural SMLs were studied as original



▲ **Figure:** Dynamic of the sea surface film formation at the air-sea interface after (a) 0; (b) 2; (c) 5; (d) 8, (e) 10, (f) 24 h; adapted from Kozarac et al., 2005.

samples and as *ex-situ* reconstructed films after previous extraction by organic solvents of different polarities (*n*-hexane and dichloromethane). Using alternating current voltammetry (*out-of-phase* mode) the concentration of SAS in SMLs was determined (Frka et al., 2009). During the investigation period the SAS concentrations in the SMLs have shown seasonal trends, and higher surfactant activities (>0.7 mg dm<sup>-3</sup> in eq. TX100) were found in the warmer May-October period compared to the winter season. It was also noticed that the SMLs from the more productive season had a higher contribution of more hydrophobic SAS. Additionally, monolayer studies comprising measurements of surface pressure-area isotherms together with scaling quantification approach (Mazurek et al., 2008) applied on the same set of SML samples have shown that higher primary production during late spring-early autumn was reflected in the presence of surface films of higher elasticity (mean elasticity

modulus  $E_{isoth}=18.33\pm2.02$  mN m<sup>-1</sup>) with the most complex film architecture (mean miscibility modulus  $\gamma=6.46\pm1.33$ ) and the highest concentrations of the lowest molecular mass film-forming material (mean molecular mass  $M_w=0.65\pm0.27$  kDa) (Frka et al., 2012). Brewster angle microscopy has proven a useful approach in the visualization of organic matter of the SML and has previously shown that during early stages of SML formation, films contain liquid-condensed domains that are most probably dominated by lipids embedded in a liquid-expanded phase as shown (Figure) (Kozarac et al., 2005).

To get an insight into that minor hydrophobic fraction, lipid material was isolated, fractionated and concentrated from the original SMLs by organic extraction and different *ex-situ* films were further investigated (Frka et al., 2009). Adsorption characteristics of *ex-situ* films and model lipids of different polarities were grouped in two distinct clusters, indicating that



nonpolar and less-polar lipids represent an important fraction of hexane extracts while more polar phospholipids were predominant in dichloromethane films. The latter ones were found to be dominant SAS of original SMLs from the late spring-autumn period in the coastal areas of the Middle Adriatic.

Our work has shown that chemical composition and distribution of the SML surfactants are influenced by the presence of certain end-member material of hydrophobic, lipid-like surfactants which strongly influenced the surface properties of natural air-sea interface. Due to their extremely high surface affinity, the presence of lipids at the interface is the result of their competitive adsorption and segregation from other macromolecular constituents which is closely related to the periods of primary production.

## References

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## Acknowledgements

This work was funded by a grant from the Croatian Ministry of Science, Education and Sports, project: Nature of organic matter, interaction with traces and surfaces in environment (No. 098-0982934-2717).

# Future Earth: from initial design to implementation



## General presentation

Future Earth is a 10-year international research programme launched in June 2012 at the UN Conference on Sustainable Development (Rio+20) that will provide critical knowledge required for societies to face the challenges posed by global environmental change and to identify opportunities for a transition to global sustainability.

Future Earth will answer fundamental questions about how and why the global environment is changing, what future changes are likely, what are the risks and implications for human development and the diversity of life on Earth, opportunities for reducing risk and vulnerability, enhancing resilience and innovation, and making the transition to a more prosperous and equitable future.

Future Earth will deliver science of the highest quality, integrating, as necessary, different disciplines from the natural and social sciences, engineering and humanities. It will be co-designed and co-produced by academics, governments, business and civil society from all around the world, encompass bottom-up ideas from the wide scientific community, be solution-oriented,

and inclusive of existing international Global Environmental Change projects and related research activities.

## Towards implementation

The initial design phase of Future Earth is now coming to a close as the Transition Team, tasked with defining frameworks for Future Earth research and governance, puts finishing touches on the final report. The report builds on a broad range of consultations with the global environmental change research community, from the visioning process to consultations on the research agenda with the GEC programmes<sup>1</sup> and projects, and regional workshops in Africa, Asia-Pacific and Latin America.

Key highlights of the report include:

- A broad research agenda that provides opportunities for research communities to come together and develop integrated and solutions-oriented research on the intersections between global environmental changes and human development, and on transformation towards sustainability
- A proposed governance structure to ensure that excellence in scientific research and stakeholder engagement, within and beyond science, can be delivered under Future Earth
- Highlights of areas of particular focus, and especially co-design of research with stakeholders, new models to

communicate science and capacity building especially towards early-career scientists around the world

- Current and future funding perspectives for global environmental change research
- Concrete steps for implementation

Recommendations focus on the need for Future Earth to build partnerships, grow with its community, and innovate to deliver on its vision.

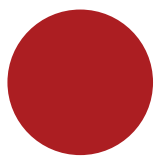
The report provides the foundation for the development of Future Earth and will inform upcoming consultations – including a second meeting with the GEC projects (including SOLAS) in the coming months. It will also inform the work of the Alliance (acting as interim Governing Council), the Science Committee, the Engagement Committee and the Interim Secretariat as they become operational.

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[1] International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme (IHDP), *Diversitas - an international programme of biodiversity science*, and World Climate Research Programme (WCRP) and Earth Science System Partnership (ESSP).

Future Earth Newsletter online: [www.icsu.org/future-earth](http://www.icsu.org/future-earth)





## SOLAS Japan

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It has been a fruitful year for Japanese SOLAS scientists; after successfully completing the W-PASS project, the NEOPS (New Ocean Paradigm on Its Biogeochemistry, Ecosystem and Sustainable Use) project, involving IMBER and SOLAS scientists, has been funded for 5 years starting summer 2012.

Additionally, a symposium entitled "Exploring the Impacts of the Fukushima Daiichi Nuclear Power Plants on the Ocean" and a public colloquium, entitled "Fukushima and the Ocean" with over 200 participants was held at the University of Tokyo in November 2012.

### Scientific highlights:

1. Dispersion of artificial caesium-134 and -137 in the western North Pacific one month after the Fukushima accident

One month after the Fukushima nuclear power plant accident in March 2011, the distribution of  $^{137}\text{Cs}$  in surface seawater was up to two orders of magnitude higher than previously recorded.  $^{134}\text{Cs}$  was also detected, in many seawater samples the  $^{134}\text{Cs}/^{137}\text{Cs}$  ratio was about 1, which indicates that radionuclides from the Fukushima nuclear power plant dispersed quickly in the western North Pacific. Numerical simulations showed that the higher caesium observed in the western North Pacific was transported not only by diffusion and advection of seawater but also via the atmosphere as aerosol.

Honda, M.C., et al. (2012). Dispersion of artificial caesium-134 and -137 in the western North Pacific one month after the Fukushima accident. *Geochem. J. (Express)*, 46, e1-e9.

2. Atmospheric inorganic nitrogen in marine aerosol and precipitation and its deposition to the North and South Pacific Oceans

By evaluating aerosol and rain samples collected over the North and South Pacific, SOLAS Japanese scientists were able to determine that wet deposition plays a more important role in the supply of atmospheric inorganic nitrogen than dry deposition. Inorganic N in aerosols composition was ~68%  $\text{NH}_4^+$  and ~32%  $\text{NO}_3^-$ , with ~81% and ~45% of each species being present on fine mode aerosol, respectively.

Jung, J., et al. (2011). Atmospheric inorganic nitrogen in marine aerosol and precipitation and its deposition to the North and South Pacific Oceans. *Journal of Atmospheric Chemistry*, 68, 157-181, 10.1007/s10874-012-9218-5.



Miri Trainic is a Post doctoral fellow in the Weizmann Institute of Science, where she also did her PhD on optical properties of organic aerosol. Her current research is in ocean-atmosphere interactions. She did her BSc in the Hebrew University of Jerusalem and her MSc at the Imperial College, London.

## Exploration of the link between *Emiliania huxleyi* bloom dynamics and aerosol fluxes to the lower atmosphere

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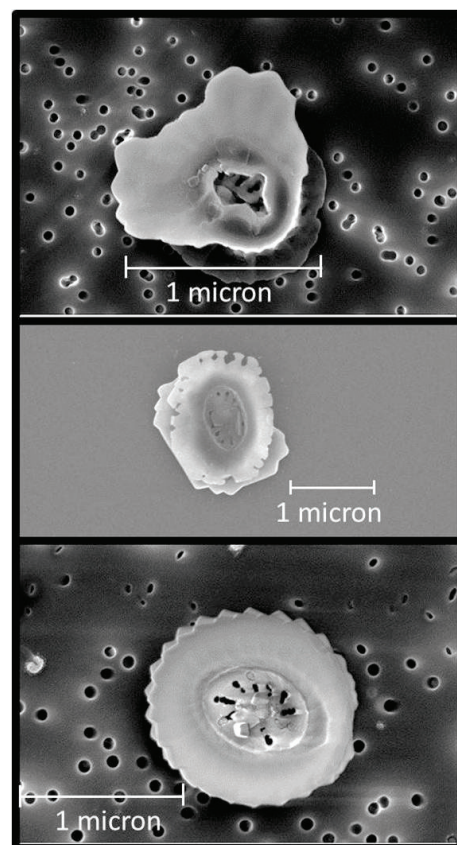
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*Emiliania huxleyi* is one of the most abundant and widely distributed phytoplankton in the ocean, forming large scale blooms in the North Atlantic Ocean during late spring. It is involved in ocean-atmosphere interactions via dimethylsulfide (DMS) emissions as well as through the formation of calcite coccoliths, accounting for a third of the total marine  $\text{CaCO}_3$  production, with profound implications on the global carbon cycle (Holligan et al., 1983; Tyrrell and Merico, 2004).

It has been shown that aerosols emitted during phytoplankton blooms may alter the properties of marine aerosols and hence their climatic effect (Fuentes et al., 2010; 2011). However, very little work was done on the effect of bloom growth phases, and specifically *E. huxleyi* blooms, on aerosol properties.

We conducted a series of controlled lab experiments to measure aerosol emissions during the growth of *E. huxleyi* strain CCMP1216. *E. huxleyi* 1216 cultures were grown in an especially designed growth chamber. The aerosols were generated in a bubbling system by flowing dry air into a sintered glass filter inside a 500ml flask containing the desired culture (Martensson et al., 2003).

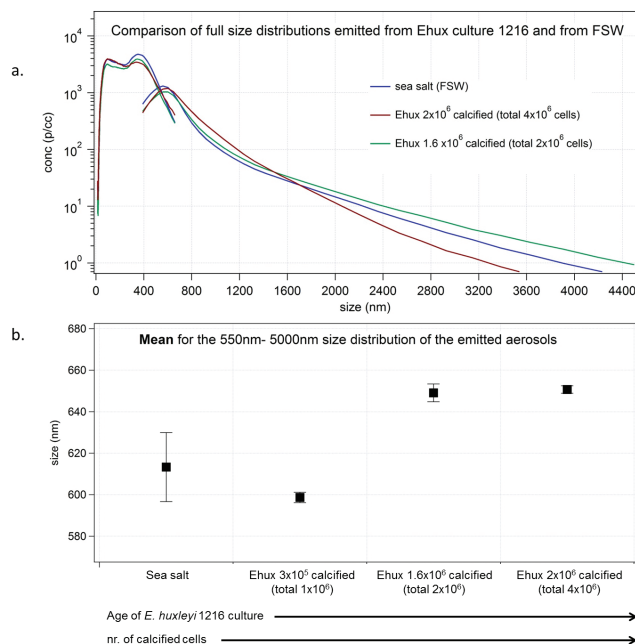
We collected the emitted aerosol particles, and performed scanning electron microscopy (SEM) analysis. Figure 1 shows SEM images of the aerosols emitted from *E. huxleyi* 1216 cultures.  $\text{CaCO}_3$  platelets from their exoskeleton are clearly observed, while coccolithophores cells were absent. The results suggest that while healthy



**Figure 1:** SEM images of aerosols emitted from *E. huxleyi* 1216 cultures. The typical structure of the coccolith platelets is clearly observed.

coccolithophore cells are too heavy to aerosolize, during cell lysis the coccoliths shed from the coccolithophore cells are emitted into the atmosphere. Therefore, aerosol production during bloom demise may be greater than from healthy *E. huxleyi* populations.





**Figure 2:** (a) Preliminary results of the aerosol size distributions emitted from *E. huxleyi* 1216, and from filtered sterilized sea water (FSW). Size distributions from 10-700nm were measured by scanning mobility particle sizer (SMPS, model 3081, TSI), an aerodynamic particle sizer (APS, model 3221, TSI) measured size distributions from 550-5000nm. (b) Comparison of the 550-5000nm size distribution mean values for aerosols emitted from *E. huxleyi* 1216 populations with increasing age and calcified cells concentration, and aerosols from FSW. Aging increases the amount of coccoliths being shed, increasing the number of platelets emitted as aerosols, the mean size grows due to the addition of the large platelets to the aerosol population.

We also investigated the size distribution of the aerosols at various stages of *E. huxleyi* 1216 growth (Figure 2). The presence of calcified cells greatly affects the size distribution of the emitted aerosol population.

This work motivated us to explore aerosols emitted during *E. huxleyi* spring bloom, in a laboratory we constructed onboard the R/V Knorr research vessel, as part of the North Atlantic Virus Infection of Coccolithophore Expedition (June-July 2012).

These results have far-reaching implications on the effect of *E. huxleyi* bloom dynamics on aerosol properties. We not only show that the *E. huxleyi* calcite shells are emitted as aerosols, but also that aerosol type and therefore chemical composition, microphysical and optical properties depend on the stage of the bloom growth.

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The International Global Atmospheric Chemistry (IGAC) project is a Core Project under the umbrella of the International Geosphere Biosphere Programme (IGBP) and co-sponsored by the international Commission on Atmospheric Composition and Global Pollution (iCACGP). IGAC's mission is to coordinate and foster atmospheric chemistry research towards a sustainable world by addressing scientific questions on emissions, atmospheric processes, and atmospheric composition and how they impact climate, human health, and ecosystems. IGAC integrates, synthesizes, guides, and adds value to research undertaken by individual scientists through initiating new activities, acting as a hub of communication for the international atmospheric chemistry research community, and through building scientific capacity. Current IGAC Activities include:

- Atmospheric Chemistry & Climate Model Intercomparison Project (ACCMIP)
- Atmospheric Chemistry & Health (AC&H)
- Aerosols, Clouds, Precipitation, and Climate (ACPC)
- Air-Ice Chemical Interactions (AICI)
- Air Pollution & Climate: A Science-Policy Dialogue
- Chemistry-Climate Model Initiative (CCMI)
- Fundamentals in Atmospheric Chemistry
- Global Emissions Initiative (GEIA)
- Halogens in the Troposphere (HiT)
- Interdisciplinary Biomass Burning Initiative (IBBI)
- IGAC China Working Group
- IGAC Americas Working Group
- IGAC India Working Group

An important component for IGAC in addressing global sustainability is working with other IGBP Core Projects, such as SOLAS, on crosscutting issues. IGAC believes strongly in collaborating with SOLAS by jointly sponsoring activities such as AICI and HiT. In addition IGAC and SOLAS jointly sponsor workshops and sessions at science conferences. IGAC is also currently exploring more crosscutting areas for collaboration with SOLAS. These areas include organic marine aerosols, remote sensing of gases at the ocean surface (e.g. glyoxal, formic acid, etc.), ocean flux measurements, the interaction of ocean biogeochemistry and the atmosphere, and atmospheric deposition over the ocean. IGAC wishes to continue its strong collaboration with SOLAS and welcomes input from the SOLAS community. For more information, visit [www.igacproject.org](http://www.igacproject.org)

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The Center for Marine Ecosystems and Climate Research (CMECLIM) at the Middle East Technical University, Turkey, is being founded by the Government of the Turkish Republic. Main objectives are to carry out experimental research in line with the objectives and research focus of the Intergovernmental Panel on Climate Change (IPCC). The center aims to provide scientific and management-related products for national institutions of Turkey as well as a global perspective in order to help enhance the climate related research.

Nationwide, the CMECLIM will act as the scientific basis for the Turkish Government to develop measures and management policies within the nation to help the global objective of preventing climate change by anthropogenic interventions.

A successful summer school titled "A view towards integrated Earth system models. Human-nature interactions in the marine world" took place in July 2012 hosted by the Middle East Technical University. The school focused on the interface between marine ecosystem biogeochemistry, physical drivers, food webs and socio-economic systems.

Scientific highlight: Influence of mineral dust transport on the chemical composition and physical properties of the Eastern Mediterranean aerosol

Koçak et al. (2012) conducted laboratory experiments and were able to determine the influence of mineral dust transport on the chemical composition and physical properties of the eastern Mediterranean aerosol. They observed that during dust events, the concentration of anthropogenic aerosol species were higher than those for non-dust events.

Koçak, M. et al. (2012). Influence of mineral dust transport on the chemical composition and physical properties of the Eastern Mediterranean aerosol. *Atmospheric Environment*, 57, 266-277



Dalin Shi is currently a professor at the State Key Laboratory of Marine Environmental Science, Xiamen University, China. His research focuses on the biogeochemical cycling of trace metals in the ocean and their roles in the global carbon and nitrogen cycles.

### Effects of ocean acidification on iron availability to marine phytoplankton

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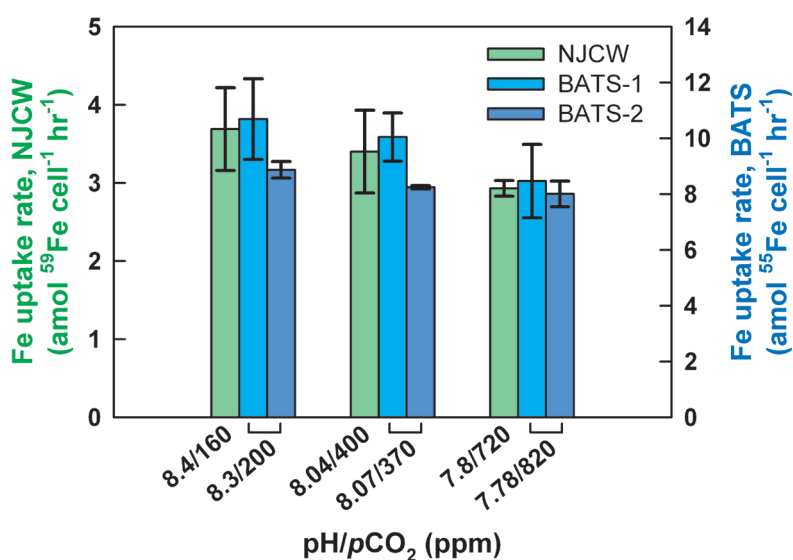
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About one-third of the anthropogenic carbon dioxide (CO<sub>2</sub>) released into the atmosphere dissolves in the ocean, increasing the partial pressure of CO<sub>2</sub> (pCO<sub>2</sub>) and lowering the pH in surface water. These changes in seawater chemistry, commonly referred to as ocean acidification, will likely have significant effects on marine phytoplankton, which are responsible for about half of the contemporary global primary production (Field et al., 1998) and form the basis of all marine food webs.

In vast areas of the oceans, the vanishingly low concentration of iron (Fe) often limits the growth of marine phytoplankton (Martin and Fitzwater, 1988). It is known that the bulk of Fe in the ocean is chelated

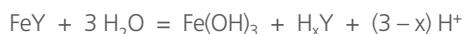
by organic compounds (Rue and Bruland, 1995), and that the availability of Fe to phytoplankton depends largely on its chemistry in seawater, which is highly sensitive to changes in pH (Shaked and Lis, 2012). We therefore examined the effect of ocean acidification on the complexation of Fe by organic ligands, and, hence, its bioavailability to phytoplankton. In the presence of organic complexing agents with various chemical functionalities, the bioavailability of dissolved Fe to model species of diatoms and coccolithophores was observed to decline at low pH. This effect is quantitatively explained by the decrease in the free Fe concentration, Fe<sup>3+</sup>, in seawater with decreasing pH and is thus not a physiological response of the organisms.



▲ Figure: Short term Fe uptake by Fe-limited *T. weissflogii* from iron bound to natural Fe-binding ligands in surface waters from the New Jersey coast (NJCW) and the Bermuda Atlantic Time-series Study (BATS) region at three different pH/pCO<sub>2</sub>. Error bars represent the standard deviation of biological replicates (n = 2 – 3) (Shi et al., 2010).



The extent to which changes in pH affect a ligand's ability to bind Fe depends on the number of protons (H<sup>+</sup>) released upon dissociation of Fe from the ligand (Y). The dissociation reactions can be written in a simplified but general form as:



The number of protons released varies between 3 (e.g., for the tetracarboxylate EDTA) and 0 (e.g., for the bis-catecholate azotochelin), and depends on the acidity of the binding moieties, the affinity of the ligand for other metals such as Ca<sup>2+</sup> and Mg<sup>2+</sup>. Consequently, the effective binding strength of ligands that release more protons is more sensitive to changes in pH. In field manipulation experiments, a slower rate of Fe uptake by *Thalassiosira weissflogii*, with decreasing pH, was observed in both coastal and oceanic Atlantic surface water samples where Fe was bound to natural Fe-chelating ligands (Figure). This result is in agreement with the laboratory data, though the magnitude of the pH effect on the uptake of Fe was modest, suggesting that little of the Fe was bound to carboxylic acid moieties or other ligands that release protons upon dissociation in the field samples (Shi et al., 2010).

We note that the decrease in Fe bioavailability caused by the change in Fe chelation at low pH is only one of several

potential effects that ocean acidification may have on Fe limitation of phytoplankton in the oceans. For example the rate of dissolution and precipitation of Fe oxides particles, through thermal or photochemical mechanisms, may also change and, perhaps, compensate for the increase in Fe complexation.

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## Outcome of the IGBP/SCOR Fast Track Initiative on 'Upper Ocean Nutrient Limitation: processes, patterns and potential changes'

Future environmental changes can be strongly influenced by variations in the nutrient availability in the oceans. Such variations influence microbial activity directly and its fundamental component in oceanic nutrient cycles. Their activity exerts a great influence in the Earth's climate by fuelling biological production, therefore keeping carbon dioxide trapped in the ocean and not being released to the atmosphere.

The paper: 'Processes and patterns of oceanic nutrient limitation' by Moore and co-authors reviews the present knowledge regarding ocean nutrient patterns and interactions. It also assesses how these patterns and interactions might be affected by future climate change and other human-made factors. Marine ecosystems are supported by marine algae, which require resources to grow and reproduce. When nutrients are not present in enough quantity, their growth is hampered and the abundance of these microscopic plants therefore reduced. The influence of nutrients is crucial to keep the microbial activity balance in the oceanic system. Without this activity, the nutrient cycling and carbon cycling in the ocean can be reduced, meaning that the amount of CO<sub>2</sub> that is being drawn from the atmosphere will be decreased. This could lead to a rise in atmospheric CO<sub>2</sub> in the atmosphere.

Moore et al. are calling for an interdisciplinary approach; likewise, to use new techniques together with observational platforms and instrumentation to tackle down the challenges and contribute to the understanding of the complex marine system and the nutrient cycling in the ocean.

This paper is an outcome of the IGBP/SCOR Fast Track Initiative on 'Upper Ocean Nutrient Limitation: processes, patterns and potential changes' and contributes to the SOLAS Mid-Term Strategy on 'Atmospheric control of nutrient cycling and production in the surface ocean'.

C. M. Moore et al. (2013) Processes and patterns of oceanic nutrient limitation. *Nature Geoscience*, 2013; DOI: 10.1038/NNGEO1765

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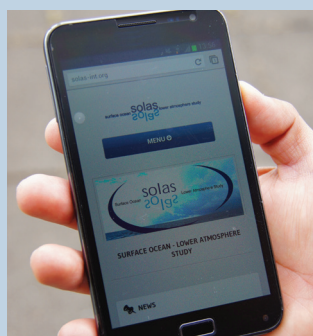
# New SOLAS website

The SOLAS website has received a new facelift. It was launched in November 2012. The new website has a clear and easy navigation system. An important new feature is the full support of mobile devices, so you can check on SOLAS on the go!

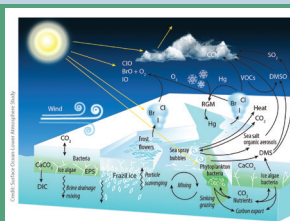
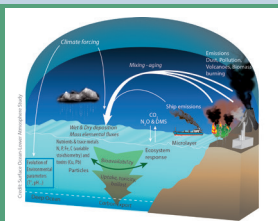
We hope you like it and we welcome your feedback to further improve it.

Our known web address remains the same:

**[www.solas-int.org](http://www.solas-int.org)**



**Visit:** [solas-int.org/figures-conceptual-diagrams.html](http://solas-int.org/figures-conceptual-diagrams.html) to obtain the SOLAS Figures & Conceptual Diagrams recently published by Law et al. 2013.





Clara Deal is a Research Associate Professor affiliated with the International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, Alaska, USA. Her current research interests include biosphere-climate interactions and feedbacks, with a focus on dimethylsulfide (DMS) and carbon cycling in the sea ice environment.

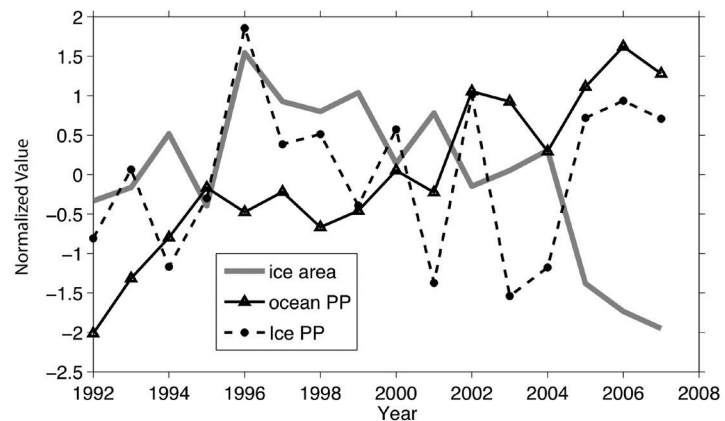
## One approach toward modeling sea ice biogeochemistry from local to Earth System scales

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Arctic sea ice is rapidly changing, shifting from a multiyear ice pack to a thinner, seasonal ice regime. An understanding of the impact of this change on the ice-associated ecosystem and biogeochemical cycling is of critical importance. With colleagues at the University of Alaska Fairbanks, we developed a local, 1-D vertical physical ice-ocean ecosystem model (PhEcoM) to predict sea ice algal biomass and primary production (PP) at individual sites in the Arctic: first-year pack ice in the seasonal ice zone (Jin et al., 2007); multiyear pack ice (Lee et al., 2010); and annual landfast ice (Jin et al., 2006).

In collaboration with members of the Los Alamos National Laboratory (LANL) Coupled Ocean Sea Ice Modeling group (COSIM), we implemented the ice biogeochemistry code from PhEcoM in the global thermodynamic/dynamic Los Alamos Sea Ice Model (CICE). In this configuration, the prognostic model extrapolates detailed information from individual sites to seasonal, regional, and pan-Arctic scales (Deal et al., 2011). Annual PP within sea ice was highest for the Bering Sea region due to high seawater nutrient concentrations. The Central Arctic Basin was second with its extensive ice coverage. Model results also displayed relatively sudden and widespread ice algal release upon ice bottom melt, and significant ice algal growth in autumn.

A motivation for this work is to investigate the influence of reduced sea ice on Arctic marine DMS emissions, which is poorly understood. Ice algae are important producers of the DMS precursor, dimethylsulfoniopropionate (DMSP). Simulations from CICE coupled to the ice DMS module of Elliott et al. (2012) suggest a strong ice algal DMS source, with large uncertainty, probably due to the key role of ice algae export from sea ice and the uncertain fate of ice DMS(P) upon entering the water column. In this regard, more work is needed since neither ice algal motility and adhesion, nor gas transport through sea ice is currently included in the model.



▲ Figure: Normalized time series of modeled sea ice area, and upper ocean 100m integrated PP and sea ice PP within the Arctic Circle (Jin et al., 2012).

Results using the CICE DMS ecosystem model coupled to the Parallel Ocean Program model (POP) indicate substantial PP in Arctic waters under sea ice, and increasing open ocean and sea ice PP during recent years despite dramatic Arctic sea ice decline (Figure 1; Jin et al., 2012). The trend in seawater DMS concentrations also appears to be increasing. Both CICE and POP are core components of the Community Earth System Model.

Nutrient supply in the above-mentioned models is based on simple formulations, whereby nutrient flux between the ocean and the ice bottom layer is a function of ice growth and as the ice bottom melts, its contents are proportionally released into the water column. A major model advancement by the LANL COSIM group accounts for brine transport (Jeffery et al., 2011), thereby including nutrient dynamics. This group is simulating biogeochemistry throughout the ice column. A new public release of CICE scheduled for 2013 includes the ice-bottom biogeochemistry code tested in uncoupled CICE with choices for nutrient transport mechanisms.

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# Update on SCOR Working Group 140 – Biogeochemical Exchange Processes at Sea Ice Interfaces (BEPSII)

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Activities within the SOLAS's Mid-Term Strategy on sea-ice biogeochemistry, has led to the successful establishment of a new SCOR Working Group in 2012: WG 140 – Biogeochemical Exchange Processes at Sea Ice Interfaces (BEPSII). BEPSII's focus is visualized in the figure. The aim of BEPSII is to improve our understanding of the role of sea ice in global biogeochemistry by bringing together sea-ice modelers and observationalists. BEPSII had its first official meeting on March 16, 2013 in Ventura, California, following the Gordon Research Conference on Polar Marine Science. BEPSII has three task groups (TG), each of which met individually and in concert with the other TGs, to discuss progress plans and timelines.

TG1 on Methodologies and Intercomparisons (Leads: Lisa Miller and Lynn Russell) has three primary goals:

1. Methodological review;
2. Intercomparisons and intercalibration projects; and 3. Guide of Best Practices. For 1, a methodological review paper is underway. For 2, dedicated projects are needed, because method intercomparisons are incompatible with multi-disciplinary process studies. Several locations are currently evaluated. For 3, two options are discussed: Producing a type of living web document and collaborating with ongoing activities for a book on sea-ice methodologies.

TG2 on Data (Leads: Klaus Meiners and Martin Vancoppenolle) has two primary goals: 1. Produce new data inventories by collation of existing data; 2. Provide recommendations for standardized protocols and databases. The first dataset on chlorophyll-a in sea ice from the Antarctic has been published (Meiners et al., 2012) through ASPeCt activities and in collaboration with BEPSII. For the Antarctic database, additional parameters (POC, DOC and nutrients) will be collected. For the Arctic, Christine Michel and Michel Gosselin have agreed to lead, also starting with chlorophyll-a. Collection methodology and motivation of collaborators will follow the example of the Antarctic. The Experience within ASPeCt and the new chlorophyll-a database will provide guidance

for standardized data-collection protocols. An overview thereof will be added into the review paper under TG1.

TG3 on Modeling (Leads: Nadja Steiner and Clara Deal) has four components:

1. Recommendations from modelers to observationalists; 2. Review papers on major biogeochemical processes; 3. Intercomparison of 1D models and publication of a review; 4. Application in regional models with links to global & regional climate modeling. With respect to 1, the aim is to create a short paper/report aiding observationalists in understanding what kind of data and variables modelers need and why and how they are useful. With respect to 2, it was decided that in lieu of one big overview paper a set of papers focusing on specific processes will be pursued. The papers would discuss the processes themselves as well as approaches for model parameterizations. Potential topics are: a) DIC/Alk separation during the freezing process, b) release and transfer of iron and other minerals, c) parameterization of light transfer in sea ice, d) processes of ice algal release into the water, e) link to atmospheric chemistry, f) parameterizations for turbulent mixing in Arctic Ocean models. In all topics, linking/bridging of scales is a leading theme. For 3, four different 1-D model intercomparison exercises were identified:

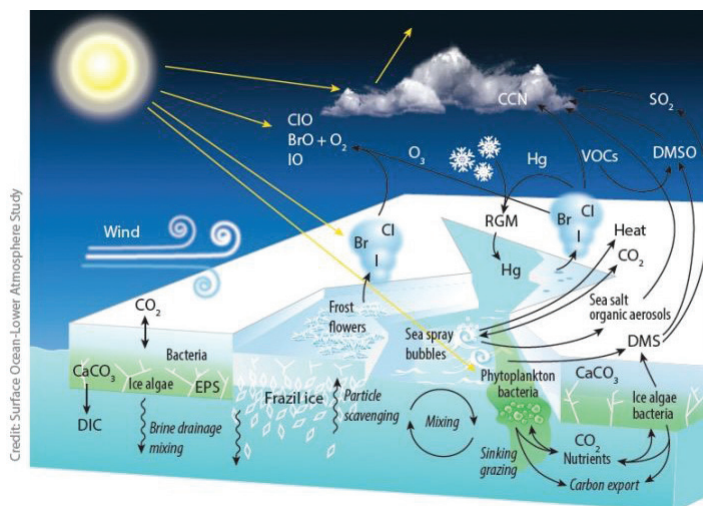
A. General ice-phytoplankton models (lead Letizia Tedesco), B. DMS (lead Clara Deal), C. Physical: convective mixing (EoS), ice thermodynamics, advection processes (lead Elena Golubeva), D. Atmosphere-ice. It was recommended to get observationalists involved in these exercises.

Activities for 4 are strongly connected with activities within AOMIP/ FAMOS. This component will deal with the applicability and relevance of small-scale processes and model parameterizations in 1-D models to the larger scale models.

New activities, meetings and outreach activities will be posted on SCOR's BEPSII ([http://www.scor-int.org/Working\\_Groups/wg140.htm](http://www.scor-int.org/Working_Groups/wg140.htm)) and the SOLAS website (<http://www.solas-int.org/activities/scor-working-group.html>)

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▲ Figure: Conceptual diagram illustrating the main issues, processes and species relating to the SOLAS Sea Ice strategy. Processes are indicated in italic. (DIC, dissolved inorganic carbon; EPS, extracellular polymeric substances; CCN, cloud condensation nuclei; RGM, reactive gaseous mercury; VOC's, volatile organic compounds; DMS, dimethyl sulfide; DMSO, dimethyl sulfoxide). From Law et al. 2013.



Rainer Volkamer is teaching Analytical Spectroscopy at the University of Colorado at Boulder. He is a Fellow of the Cooperative Institute for Research on Environmental Sciences, and member of the Humboldt Network.

Mitsuo Uematsu is Director and Professor of the Center for International Collaboration, Atmosphere and Ocean Research Institute (AORI) at the University of Tokyo. Hiroshi Furutani is a Research Scientist at AORI.

## Up and beyond the surface ocean – tropical ocean impacts on the chemistry of the upper free troposphere

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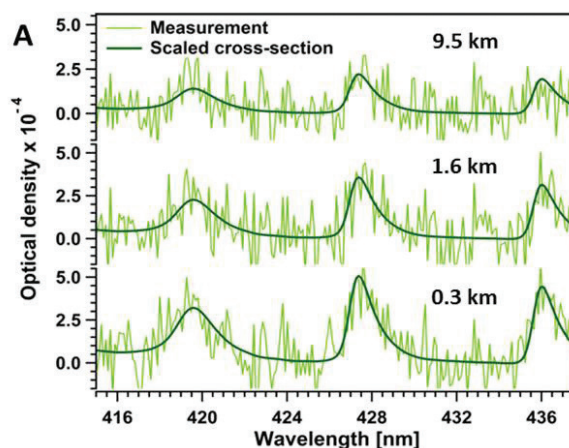
TORERO (Tropical Ocean tRoposphere Exchange of Reactive halogen species and Oxygenated hydrocarbons, January-March 2012) probed air-sea exchange of very reactive trace-gases from diverse ocean environments of the Humboldt current, and their redistribution by tropical deep convection impacts the chemistry of the tropical free troposphere. 17 research flights were conducted using the NSF/NCAR Gulfstream V aircraft (PI: R. Volkamer), equipped with a suite of chemistry and physics instruments, and the NOAA R/V Ka'imimoana to constrain air-sea fluxes of reactive trace-gases including incl. bromine oxide (BrO), iodine oxide (IO), very short lived halogen species (VSHS), VOC, OVOC (some 50+ species), aerosol size distributions, optical properties, and photolysis frequencies over the full tropospheric air column (0-15km altitude) between 40N to 40S latitude over the eastern tropical Pacific Ocean. The aircraft probed air above Eastern Boundary Upwelling Systems (EBUS) off the coasts of Chile and Peru, larger scale upwelling to the west of Gallapagos Islands, and contrasted these productive waters with the oligotrophic Pacific ocean gyre in the Southern Hemisphere.

EqPOS (Equatorial Pacific Ocean Stratospheric/Tropospheric Atmospheric Study, January-March 2012) research cruise, conducted along the equator in the eastern Pacific Ocean by R/V Hakuho Maru (PI: M. Uematsu), provided an unique opportunity to observe ocean and atmosphere from 30 km above to 6 km below the ocean surface, in addition to their interface. The long list of on-board measurements and activities are stratospheric air sampling and vertical profiling of O<sub>3</sub>, CO<sub>2</sub>, and water vapor by launching stratospheric

balloons, which were coordinated with the aircraft observation by the TORERO project, continuous characterization of atmospheric aerosols and trace gases in marine boundary layer, in-situ flux observation of CO<sub>2</sub>, dimethyl sulfide (DMS), and other volatile organic compounds, sea surface microlayer sampling and chemical characterization, biogeochemical characterizations of dissolved and particulate matter, zooplankton and phytoplankton including nitrogen fixing organisms, and microbial diversity in seawater. These coordinated simultaneous oceanic and atmospheric observations should provide a unique view of biogeochemical processes and their relationship to the environment and ecosystem in the equatorial region of the Pacific Ocean.

The tropical free troposphere is a particularly relevant atmospheric environment to climate. Surprisingly, we find ~ 0.05 – 0.25ppt (1 ppt = 1 parts per trillion = 10<sup>-12</sup> volume mixing ratio) IO radicals are present over most of the tropospheric air

column also over the Eastern Pacific Ocean. Such elevated IO in a decoupled transition layer (0.8-1.8km altitude) is found to be inconsistent with the IO lifetime. Our data suggests that iodine recycles from aerosols back to the gas-phase as a result of multiphase chemical reactions in aerosols / at the surface of aerosols (Dix et al., 2013, PNAS). The widespread abundance of IO (and also BrO) over the Eastern Pacific ocean confirms our earlier observations over the Central Pacific and extends recent observations of very short-lived and water soluble oxygenated VOC like glyoxal (lifetime ~ 2-3 hrs) (Sinreich et al., 2010) that remain unexplained by atmospheric models (Myriokefalitakis et al., 2008) towards other OVOC species (butanal, methyl ethyl ketone). Aerosols present a vehicle to transport chemically active trace constituents (halogens and organic carbon) from the ocean surface into the upper air, where the climatic relevance is enhanced by the lack of sinks, more abundant light, and very different environmental parameters.



▲ Figure 1: Spectral proof for the presence of small amounts of iodine oxide in the tropical free troposphere. Adapted from Dix et al., 2013.



For example, even very small IO amounts –while hard to detect– account for about 10% of the loss rate for tropospheric ozone, and are thus relevant to atmospheric chemistry and climate. Most tropospheric ozone mass resides in the tropics ( $O_3$  is a greenhouse gas), 60–80% of the global methane destruction is initiated by the photolysis of this ozone, and mercury oxidation rates are accelerated at the low temperatures characteristic of the tropical free troposphere. The EqPOS and TORERO teams have further collaborated in joint laboratory experiments at the University of Toronto (Zhou et al., 2013, submitted to ACP), using real sea surface microlayer samples from the Eastern Pacific ocean to study the volatilization of OVOC products as the result of heterogeneous chemical reactions of atmospheric oxidants at the air-sea boundary, and on aerosol surfaces.

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## Acknowledgements

The TORERO team acknowledges funding from US-NSF under award AGS 1104104, NCAR/RAF and EOL for operating the NSF/NCAR GV, the NOAA/TAO program, captain and crew of R/V Ka'imimoana for their assistance during the KA-12-1 TORERO research cruise. EpPOS team gratefully acknowledges captain and crew of the R/V Hakuo Maru for their assistance during KH-12-1 EqPOS research cruise. The US-Japanese collaboration was facilitated by the SOLAS program.



▲ **Figure 2:** Launching of a stratospheric balloon from R/V Hakuo Maru for stratospheric air sampling and vertical profiling of  $O_3$ ,  $CO_2$ , and water vapour.

# Workshop on 'Towards an integrative regional coupling in the Eastern Boundary Upwelling Systems'

26–28 November 2012  
Lima, Peru

This meeting is a follow up of the two previous workshops carried out within the Mid-Term Strategy Initiative on "Air-sea gas fluxes at Eastern Boundary upwelling and Oxygen Minimum Zone (OMZ) systems", it was held at the Instituto Geofísico del Peru (IGP) since its goal was to establish strong links between the CLIVAR and SOLAS communities to reach an integrated modelling and observational approach for a proper regional assessment of climate change impact on this OMZ region off Peru.

This three day-meeting was structured with two days of scientific presentations and discussions followed by one day of a series of eight lectures devoted to capacity building for Peruvian Master and PhD students (some of the lectures can be found at <http://solas-int.org/mts/research-strategy-5.html>). The SOLAS IPO, the German SOPRAN program, the French IRD and LEGOS and the Peruvian IGP provided the funding to hold this event.

The following general topics were covered during the first two days: Surface (energy

and water) fluxes at the air-sea interface (in situ measurements of fluxes and satellite-based flux estimates), and Towards an integrative regional coupling in the EBUS: modelling and observations (in situ and remote sensing): atmosphere, physical and biogeochemical dynamics.

During the second day, the focus was more on the Peru system by looking at El Niño events in the Peru EBUS and the definition of two independent indices, one for SST off the coast of South America and the other in the eastern-central equatorial Pacific

The second topic of the workshop was then tackled directly towards biogeochemical implications. Modeling efforts with the ROMS/BIOEBUS modeling platform showed the relative contribution of two major nitrogen loss mechanisms, denitrification and anammox in the OMZ off Peru.

A modelling study explored the changes in oceanic  $N_2O$  cycling and net flux from the OMZ regions in response to perturbations (changes in extent of oxygen minimum

zones, increased nutrient supply). The future evolution of multiple stressors in EBUS was then apprehended with model simulations. They showed that ocean acidification in EBUS is primarily driven by atmospheric  $CO_2$  rise while warming and stratification and local wind changes have a much smaller impact. In contrast, deoxygenation is quite sensitive to physical perturbations with large differences in response between the EBUS reflecting the difference in underlying processes governing the regional oxygen balance.

For more information about the workshop please visit our website: [www.solas-int.org](http://www.solas-int.org) or contact the workshop conveners Véronique Garçon ([veronique.garcon@legos.obs-mip.fr](mailto:veronique.garcon@legos.obs-mip.fr)), Ken Takahashi ([ken.takahashi.igp@gmail.com](mailto:ken.takahashi.igp@gmail.com)) and Boris Dewitte ([boris.dewitte@gmail.com](mailto:boris.dewitte@gmail.com)).

# SOLAS/IGAC Halogens in the Troposphere task team (HitT)



Sumi Wren received her B.Sc. Chemistry from Queens University (2006) and her B.Ed. from the University of Toronto (2007). She spent a year teaching before commencing her PhD degree in the Donaldson group. There, she has been developing spectroscopic tools to study chemical processes at water and ice surfaces.

## Is the sea ice surface buffered against pH change?

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In the polar regions, the activation and release of reactive bromine species (RBS) from sea ice surfaces leads to springtime ozone depletion and mercury oxidation events. The autocatalytic cycle that leads to the formation of RBS (the so-called 'bromine explosion') is thought to be acid-assisted, and in the aqueous phase would be essentially shut off at the alkaline pH of seawater. But what is the pH of a sea ice surface? Is it, like seawater, buffered against pH changes? It has been proposed that the precipitation of carbonate salts during sea ice formation could reduce its buffering capacity, enabling acidification by trace acids and thereby triggering bromine explosion chemistry (Sander et al., 2006). Testing this hypothesis requires techniques that permit direct interrogation of the surface.

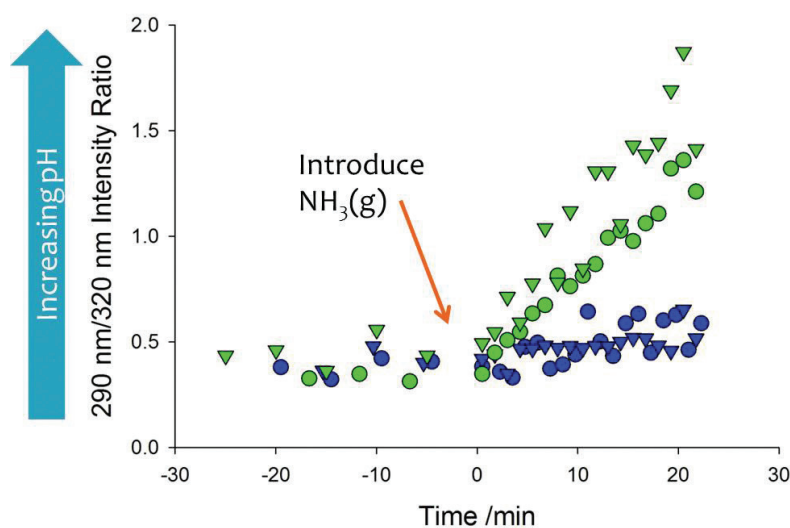
In our lab we have developed techniques for investigating pH changes at aqueous and frozen interfaces (Wren and Donaldson, 2012a; 2012b). Using this technique we have investigated the possible exclusion of  $\text{H}_3\text{O}^+$  and  $\text{OH}^-$  ions due to freezing, and studied changes in interfacial pH at water, pure ice, frozen salt water and artificial sea ice surfaces due to acid or base deposition. The technique combines glancing-angle laser-induced fluorescence (LIF) with pH-sensitive fluorescent dyes; the surface sensitivity lies in the glancing-angle geometry, the surface activity of the dyes, and depositing species from the gas phase. For salty surfaces, we use the dye harmine, exploiting the pH dependence of its excitation spectrum. We find that the ratio of fluorescence intensities upon excitation at 290 nm and 320 nm (the '290/320 ratio') reflects the relative abundances of

the neutral and protonated forms and hence the local pH (Wren and Donaldson, 2012a,b).

To investigate the buffering capacity at frozen salt water and sea ice surfaces we studied changes in pH due to the deposition of  $\text{NH}_3(\text{g})$ . The figure shows that deposition of  $\text{NH}_3(\text{g})$  to a frozen salt water surface leads to an increase in the 290/320 ratio, from which we infer an increase in surface pH, as expected. However, deposition of  $\text{NH}_3(\text{g})$  to an artificial sea ice surfaces leads to little change in the 290/320 ratio, indicating, little to no increase in surface pH. Both frozen surfaces are expected to be covered by a thin brine layer which forms during freezing due to the exclusion of

salts from the bulk. However, the results obtained at the artificial sea ice surface suggest that its brine is resistant to changes in pH, implying a maintained buffering capacity there. Our work supports a recent modelling study which shows that the ultimate reduction in brine alkalinity depends on the identity of the precipitating carbonate salt, with no reduction expected when ikaite ( $\text{CaCO}_3 \cdot 6\text{H}_2\text{O}$ ) precipitates (Morin et al., 2008).

In conclusion, our work shows that brine covering sea ice surfaces may remain basic, which has important implications for our understanding of bromine explosion chemistry. Importantly, we have developed a useful tool for studying pH at frozen



▲ Figure: The harmine 290/320 ratio measured at the surface of a frozen 0.5 M NaCl(aq) solution (green symbols) and at the surface of artificial sea ice made from Instant Ocean (blue symbols) as a function of time. A constant flow of  $\text{NH}_3(\text{g})$  in  $\text{N}_2$  was introduced at  $t = 0$ . Reproduced from Wren and Donaldson, (2012b).

surfaces. The next step will be to extend our technique to the field.

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Wren, S. N. and Donaldson, D. J. (2012b). How does deposition of gas phase species affect pH at frozen salty interfaces? *Atmos. Chem. Phys.*, 12: 10065 – 10073

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## Acknowledgements

This work was funded by NSERC.

# Workshop on 'HitT – Climate impact of seasalt-derived Cl atoms'

17-19 December 2012  
Kiel, Germany

The main goal of the Halogens in the Troposphere (HitT) SOLAS/IGAC task team is to determine and quantify the importance of reactive halogen compounds in tropospheric chemistry and climate forcing.

The most relevant climate impact of tropospheric halogen chemistry could be the impact of Cl atom oxidation on methane concentrations. However there are still very large uncertainties in the quantitative importance of this methane loss pathway, basically spanning from 0% contribution to 15+%. In order to improve knowledge of this important process, a workshop was co-sponsored by SOLAS and IGAC reuniting 22 participants, including eight early career scientists.

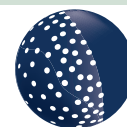
The workshop overarching questions were a) is tropospheric Cl chemistry a significant aspect of atmospheric reactivity, and to what extent is it a natural vs. anthropogenic effect? b) Do we have to include Cl chemistry in future climate models to improve the calculation of the radiative forcing and if so, what level of process understanding is required?

On the first day a review of the current state-of-the-art of atmospheric Cl cycling was given through scientific presentations by the participants and the following two days were used to discuss how to best address the two main questions.

The discussions highlighted the need for additional laboratory, instrumentation development, field studies and modelling, and it quickly became clear that all three approaches are required to accurately assess the climate impact of atmospheric chlorine. Several funded modelling projects are ongoing (e.g., at Leeds and Norwich) which are trying to produce a global picture of the relevance of chlorine chemistry and focused field campaigns are being planned for Europe, North America, and a marine site (most likely on the Bermuda).

More info at: <http://www.solas-int.org/activities/task-teams.html>

The workshop was led by Roland von Glasow (r.von-glasow@uea.ac.uk) and Eric Saltzman (esaltzma@uci.edu).



Earth  
System  
Governance

## Advancing research and strengthening science policy on ocean governance

Oceans provide resources that are important components of the biogeochemical systems of our planet. Human impacts on the resilience of marine systems are less apparent than anthropogenic impacts on terrestrial and atmospheric systems. Yet, enough is known to recognize that the oceans are in peril as a result of human actions including overexploitation, pollution, habitat destruction, and climate change and its consequences. This requires a better understanding of oceans and the development of innovative policy solutions.

This challenge has been taken up by the Earth System Governance global research alliance, the largest social science research network in the area of governance and global environmental change. In a recently established task force, the project will synthesize relevant social science research, e.g. on regime fragmentation, law of the seas, governance of areas beyond national jurisdictions, fishery and resource extraction policies and marine protected area management. In parallel, the task force will advance research on ocean governance. It will do so as the central node on interdisciplinary and internationally organized ocean governance research in the Project, and by seeking active collaboration with the research community of other projects in the global environmental research community like for example SOLAS, LOICZ and IMBER.

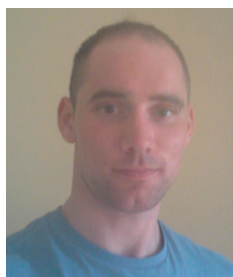
To assist policy responses and strengthen the science-policy interface on ocean governance, the Project, jointly with many other organisations including UNESCO-IOC and the Luso-American Foundation, among others, is a founding partner of the Future Ocean Alliance (FOA), a nongovernmental association whose mission is to join together people producing ocean governance knowledge, needing to use this knowledge, or showing an interest in supporting ocean governance research and implementation.

The coordinated research effort by the Earth System Governance Project, soon complemented with the expertise of other global environmental change projects, is thus embedded in, contributing to, and co-producing knowledge with the myriad of ocean policy processes at the regional and global level. It will bring ocean research strongly into the emerging Future Earth initiative, and advance research and policy making for ocean sustainability.

Ruben Zondervan, Executive Director  
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# SOLAS Focus 2: Exchange processes at the air-sea interface



Brian Scanlon is currently on his second year as a PhD student in the AirSea Laboratory at the National University of Ireland Galway. His primary research interests include whitecaps, 1-dimensional oceanic turbulence models, and air-sea interactions.

## Wave breaking at the ocean surface: distinguishing between different forms of whitecaps

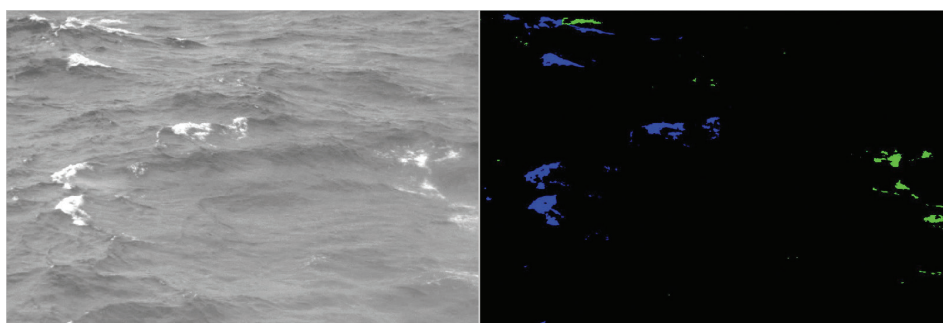
B. Scanlon

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Wave breaking at the ocean surface is critical for the air-sea exchange of greenhouse gases, heat, and momentum, as it disrupts the ocean surface and allows material to be transported across the air-sea interface in localised bursts. Wave breaking is quantified by measuring the coverage of whitecaps (W) at the sea surface using imaging techniques which can determine the percentage ratio of breaking to non-breaking ocean surface. Although W is controlled by several environmental factors (e.g. surfactants, temperature, salinity), it is primarily determined using wind speed as a proxy. There exists many parameterisations that attempt to predict W in terms of wind speed, but there is variability within the reported literature by factors of 100 and more (Anguelova and Webster, 2006).

Whitecapping consists of two stages: active wave breaking (stage A - WA) and mature white-capping (stage B WB). Stage A whitecaps have a high air-sea mixing potential and correspond well to the rate of wave breaking, appealing its quantification to gas transfer studies (Asher and Wanninkhof, 1998) and wind-wave studies and are also directly related to wave-field energy dissipation, causing increased turbulence in the oceanic mixed layer directly beneath. The bubble bursting nature of stage B whitecaps makes WB appealing to aerosol production studies.

Surfactants can increase WB (Callaghan et al., 2013). Surfactants are produced by marine organics and can be quantified by relating to the concentration of chlorophyll present.



▲ Figure: Raw sea surface image (left) and processed image (right). Blue represents stage A whitecap pixels and green represents stage B whitecap pixels.

Few authors have attempted to distinguish between WA and WB due to added complexity of separation. Previous studies used similar methods of distinguishing the two stages by spectral intensity (brightness) based techniques which relies on the assumption that the spectral intensity of stage A is always greater than that of stage B whitecaps. However, this is not always the case as the albedo of stage B whitecaps can often be similar and even higher than that of stage A.

Using a self-developed technique, we are proposing to improve on estimations of WA and WB against a range of meteorological parameters known to enhance wave breaking. This will be carried out by extracting values of WA and WB from 64,000 high resolution images of the sea surface acquired during an experiment in the North Atlantic Ocean. The method of separation between stage A and stage B takes advantage of image processing techniques (developed at NUIG) by allowing the user to visually distinguish each

whitecap pixel as either stage A or stage B with high efficiency and ease of use, significantly reducing uncertainties evident in previously used methods (Figure). The project will attempt to explain the high variability of W previously recorded.

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# Oceanflux projects: a collaboration between the European Space Agency (ESA) and SOLAS



**oceanflux**

support to science element

The three Oceanflux projects aim at studying processes at the air sea interface using satellite observations. Oceanflux is part of the ESA Support to Science Element, an element of the Earth Observation Envelope Program which has the goal to reinforce the scientific component of the ESA Living Planet programme. Oceanflux has been developed in close collaboration with SOLAS. The projects started in November 2011 and will come to an end in autumn/winter 2013.

Read below some updates about each of the Oceanflux projects.

## Oceanflux: sea spray aerosol (OSSA)

<http://oceanflux.fmi.fi/>

The project aim at improving the parameterization of the sea spray source function for use in models (CTM and GCM) to evaluate climate effects due to background aerosol, and in response to climate change. It also aims at improving estimates of the direct and indirect radiative effects of sea-spray aerosol; which is needed to provide the natural effects to contrast anthropogenic forcing and estimate effects of climate change.

The project partners are the Finnish Meteorological Institute in Finland, the National University of Ireland Galway in Ireland and the Netherlands Organization for Applied Scientific Research in The Netherlands. The principal investigators are Gerrit de Leeuw, Colin O'Dowd and Astrid Manders.

A science workshop is planned in Galway, Ireland on 30 Sept. and 1 Oct. 2013 entitled "Open Sea Spray Aerosol Workshop".

## Oceanflux: climatically-active gases in the Eastern Boundary Upwelling and Oxygen Minimum Zone (OMZ) systems

<http://upwelling.eu>

The EBUS (Eastern Boundary Upwelling Systems) and OMZs (Oxygen Minimum Zone) contribute very significantly to the gas exchange between the ocean and the atmosphere, notably with respect to the

greenhouse gases (GHG). Off Peru, very few in-situ data are available presently, which justifies alternative approaches for assessing these fluxes. GHG air-sea fluxes determination can be inferred from inverse modeling applied to vertical column densities from GOSAT, using state of the art modeling, at low spatial resolution. For accurately linking sources of GHGs to EBUS and OMZs, the resolution of the source regions needs to be increased. This task develops on new non-linear and multiscale processing methods for complex signals to infer a higher spatial resolution mapping of the fluxes and the associated sinks and sources between the atmosphere and the ocean. The use of coupled satellite data (e.g. SST and/or Ocean colour) that carry turbulence information associated to ocean dynamics is taken into account at unprecedented detail level to incorporate turbulence effects in the evaluation of the air-sea fluxes. A framework is presented as described above for determining sources and sinks of GHG from satellite remote sensing with the Peru OMZ as a test bed.

The research is led by an interdisciplinary consortium between Centre National de la Recherche Scientifique-LEGOS in France and the University of Heidelberg in Germany. The consortium researchers leading the project are Christoph Garbe, Véronique Garçon, André Butz, Boris Dewitte, Aurélien Paulmier, Joel Sudre, Isabelle Dadou and Hussein Yahia.

Two events in 2012 were held by the principal investigators, these were in the European Geosciences Union (EGU) in Vienna, Austria and in SOLAS Open Science Conference in Seattle, USA.

## Oceanflux: greenhouse gases

<http://www.oceanflux-ghg.org/>

Information on the project including an active blog describing recent highlights is maintained on the web site.

The goal of the project is to develop and validate new and innovative products combining field data, satellite observations, and models. Major scientific challenges concern the estimate of the gas transfer velocity parameter, from which the air-sea flux of CO<sub>2</sub> can be determined, and the quantification of the impact of biological slicks, rainfall, sea surface temperature and salinity variability on the air-sea CO<sub>2</sub> flux.



## SOLAS Ireland

National representative:

Brian Ward

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One of the major highlights for SOLAS Ireland was the participation in the Sub Tropical Atlantic Surface Salinity Experiment cruise which took place in August 2012 in collaboration with the LOCEAN Laboratory in Paris. The main objective of the cruise was to study the processes that are controlling the North Atlantic Salinity Maximum. Data was retrieved through deployment of the ASIP profiler and a complete underway carbon system (pCO<sub>2</sub>, DIC, pH and alkalinity).

Another participation took place in the M90 research expedition in the Eastern Tropical South Pacific, focusing on the oxygen minimum zone along 85°50'W and studying the distribution and speciation of redox sensitive trace elements, particularly in regard to dust inputs (e.g. Ti, Mn & Fe) and to oxygen control of redox cycles (e.g. Iodine & H<sub>2</sub>O<sub>2</sub>). This work was carried out in cooperation with German, French and Peruvian research.

Another important international collaboration with the WCRP Data Advisory Council was established by SOLAS national representative Brian Ward accepting the invitation to serve as a member for three years.

Future goals for the Irish SOLAS scientists include a participation in the Subtropical North Atlantic SPURS air-sea freshwater flux experiment; a deployment of the new photoacoustic gas analyser for air-sea eddy covariance flux measurements and the deployment of a new micro-rosette for autonomous DIC measurements in the ocean.

Scientific highlight: Wave-turbulence scaling in the ocean mixed layer

Sutherland et al. (2012) carried out a comparison of their collected data during the Knorr11 gas exchange cruise regarding the profiles of turbulent kinetic energy dissipation rate against various proposed scalings. The results were found to be consistent with what was to be expected for a purely shear-driven wall layer, contrasting with many recent studies which suggest higher rates of turbulent kinetic energy dissipation in the near ocean surface. Verification of these models will allow the SOLAS scientists to parameterize the gas exchange coefficient with estimates of dissipation.

Sutherland, G., Christensen, K.H., and Ward, B. (2012). Wave-turbulence scaling in the ocean mixed layer *Ocean Sci. Discuss.*, 9, 3761-3793, doi:10.5194/osd-9-3761-2012.

There are two technical foci to this work: a) the first is the generation of global climatologies, including a project dataset that will be available for the international scientific community to exploit and scrutinise, but also climatologies generated by SOLAS scientists external to the project and b) the second is underpinning scientific investigations to address the main uncertainties inherent in the calculation of air-sea gas flux climatology.

The project is led by David Woolf of Heriot Watt University (HWU) in UK. North Highland College (UHI) is the lead organisation, while Plymouth Marine Laboratory (UK), IFREMER (France), NOC (UK) and HWU are partners.

The project has made an online data catalogue available. A comprehensive data processing system allowing calculation of global climatologies that exploits this data catalogue will be released soon. SOLAS scientists are invited to use this system. An example output from the data processing system can be seen at [http://www.oceanflux-ghg.org/var/storage/images/medias-ifremer/medias-oceanflux/images/daily-mean-co2-flux/881291-1-eng-GB/Daily-mean-CO2-flux\\_gallery\\_viewer\\_catcher.png](http://www.oceanflux-ghg.org/var/storage/images/medias-ifremer/medias-oceanflux/images/daily-mean-co2-flux/881291-1-eng-GB/Daily-mean-CO2-flux_gallery_viewer_catcher.png). This system exploits cloud based data processing technologies.

An international science workshop is planned in Brest, France on 24-27 September 2013 entitled "ESA-EGU Air-sea

Gas Flux Climatology; Progress and Future Prospects workshop". Registration, abstract submissions and applications for travel grants are open until 31 May 2013.

The aim of the workshop is to build a picture of the existing capability in air-sea gas flux climatology and to look ahead to new challenges and opportunities.

The full participation of SOLAS scientists in the workshop, the generation of new climatologies and constructive criticism of all scientific, technical and policy elements is actively encouraged. The project receives advice from the SOLAS community through a Reference User Group and through the organisation of the workshop, but individual communications are always welcome.

## ESA's Climate Change Initiative: Developing longtime series of satellite data for climate research

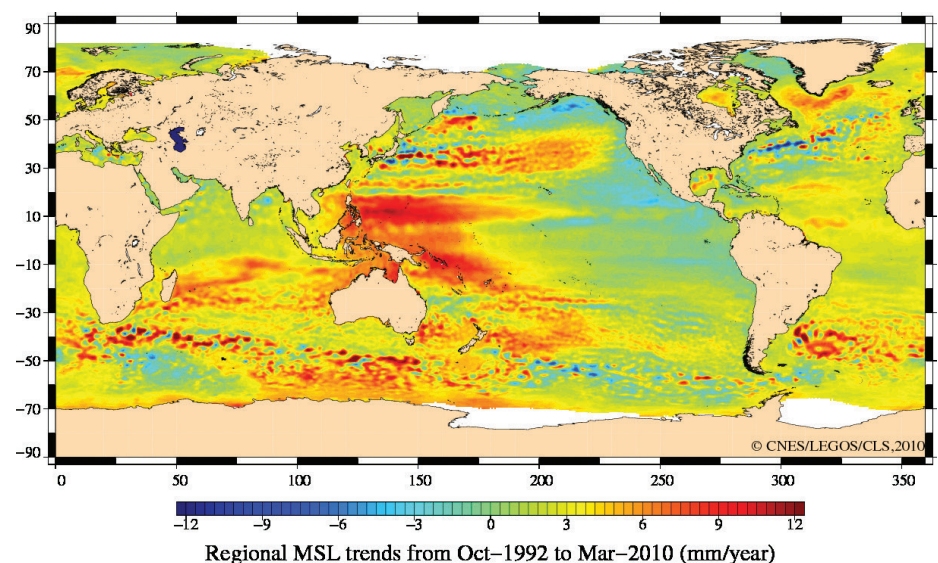
C. Downy  
ESA Climate Office, Harwell  
Contact: [cat.downy@esa.int](mailto:cat.downy@esa.int)



The ESA Climate Change Initiative aims to improve the use of satellite data by combining and collating multiple existing data sets (from ESA and third parties) to deliver climate data records for 13 'Essential Climate Variables' (ECV's) (Hollmann et al., 2013). The first data sets from the programme are now available to researchers to download and provide feedback.

Each team took the requirements set out by the Global Climate Observing System and identified further requirements from their community, then designed their products to match as many of the specified needs as possible. The ECVs all build and improve upon existing satellite data products by the inclusion of new sensors, increasing coverage, or by building the first complete records. All projects have focused on improving the representation of uncertainty values in the data sets. The ECVs most relevant to the SOLAS community are highlighted below:

**Aerosol:** Aerosol\_cci is focused on improving the accuracy of aerosol optical depth (AOD) retrieval and improving the quality of European aerosol products. Aerosol\_cci products include: AOD,



▲ **Figure 1:** Regional map of mean sea level trends from October 1992 to March 2010 from CCI Sea Level. Some regions experience a rise of up to 10 mm per year (dark red), while others see a decrease of about 10 mm per year (dark blue). On average, the global sea level rises about 3 mm every year.

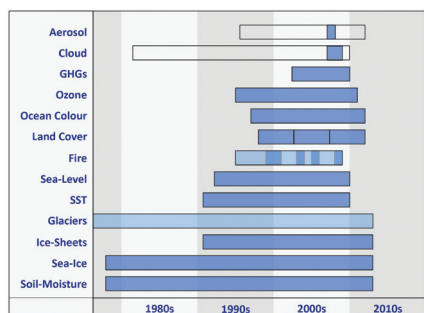
stratospheric aerosol extinction profiles and aerosol absorption index.

**Cloud:** The Cloud\_cci data products provide multiple derived cloud properties from 2007-2009: cloud mask; cloud-top parameters; microphysical properties and subsequently derived cloud water paths; and combined products (ISCCP-like histograms).

**Ocean Colour:** The Ocean\_Colour\_cci product list includes phytoplankton Chlorophyll-a concentration, Apparent Optical Properties and Inherent Optical Properties.

**Sea Level:** Sea\_Level\_cci is developing a mono-satellite product from Level-2 altimeter data and a combined multi-satellite ECV product. This consists of a time series of monthly, gridded Sea Level





▲ **Figure 2:** Temporal extent of the full set of CCI data sets. Lighter blue denotes times when coverage is not at its maximum, e.g. regional studies or areas of sparse data and clear boxes denote plans to extend the data sets in the next phase of the programme.

Anomalies with oceanic indicators of global mean sea level and regional mean sea level trends (Figure 1).

**Sea Surface Temperature:** The main SST\_cci product will be a daily SST record based on ATSRs and AVHRRs. The ATSR SSTs in SST\_cci products will be the most accurate ( $\leq 0.1$  K bias, all regions) and stable (constant calibration to  $< 0.005^\circ\text{C/yr}$ ) obtained from space.

**Sea Ice:** Two Sea\_Ice\_cci data products will be provided: Sea ice concentration, available for both hemispheres daily, at 50 km resolution, and sea ice thickness, available for the Arctic Ocean on a monthly basis at 100 km.

The data sets (Figure 2) will be made available through the project websites, all of which are accessible through the main CCI website [www.esa-cci.org](http://www.esa-cci.org). Here you can find details on the different parameters provided within each project, including spatial and temporal resolution, as well as the satellites and sensors used.

## References

Hollmann, R. et al. (2013). The ESA Climate Change Initiative: satellite data records for essential climate variables Bulletin of the American Meteorological Society. doi: <http://dx.doi.org/10.1175/BAMS-D-11-00254.1>

## SOLAS Germany

National representative:

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The German SOPRAN (Surface Ocean Processes in the Anthropocene, [www.sopran.pangaea.de](http://www.sopran.pangaea.de)) project has received funding for a third phase from 1st February 2013 until 31st January 2016. Since 2007, SOPRAN is funded by the German Federal Ministry of Education and Research. In its third phase SOPRAN involves 37 PIs from eight partner institutions working in 26 subprojects. Major activities are the Meteor Cruise M91 to the upwelling off Peru (December 2012) and a joint SOPRAN/BIOACID mesocosm experiment off the Canary Islands in spring 2014. Moreover, SOPRAN III is supporting the SOLAS IPO in Kiel. The subprojects are organised within three inter-related themes: (1) climate relevant trace gas fluxes, (2) air-sea exchange processes and the surface microlayer and (3) oceanic responses to atmospheric drivers. Overarching activities of SOPRAN III include project coordination and data management. The Kick-off meeting of SOPRAN III (which was also the 6th SOPRAN Annual Meeting) was hosted by the Leibniz-Institut für Troposphärenforschung (TROPOS) and took place in Leipzig on 19/20 March 2013. More than 50 scientists came together to present their recent findings and discuss future activities. The first day saw overview talks by Ina Tegen and Thomas Müller (both from TROPOS) as well as Hermann Bange (GEOMAR) followed by two "Young Scientist Highlight Presentations" of Steffen Fuhlbrügge (GEOMAR) and Kanneh Fomba (TROPOS). During the poster session on Tuesday afternoon more than 40 posters were presented and sparked many lively discussions about the presented results. The oral and poster presentations covered the broad thematic spectrum of SOPRAN including measurements from atmosphere/ocean observatories at the Cape Verde Islands, results from SOPRAN cruises to the tropical Atlantic Ocean/Mauritanian upwelling and the upwelling off Peru, studies of the air-sea gas exchange in the Heidelberg Aeolotron, CO<sub>2</sub> enrichment experiments, halocarbon production and emissions as well as aerosol chemistry and physics. On Wednesday morning the upcoming activities during the next three years of SOPRAN III were introduced by the Theme leaders and discussed in detail in working groups. The 7th SOPRAN Annual Meeting will be hosted by the University of Bremen in March 2014.

## The oceanflux greenhouse gases project

SCIENCE WORKSHOP  
24-27 Sept. 2013  
BREST | FRANCE

The project aims to improve the quantification of air-sea exchanges of greenhouse gases, of prime importance in the climate system.

This workshop is aimed at scientists, engineers, and Reference User Group members. Goals of this workshop are:

- allow the partners to present their results
- gain user feedback
- plan future aims and collaborations

For application and more info on the workshop, visit the project website at: [www.oceanflux-ghg.org](http://www.oceanflux-ghg.org)

News about recent developments including scientific results, can be found in the project blog: <http://oceanflux-ghg.blogspot.fr>



# 6th SOLAS International Summer School

The 6th SOLAS Summer School will take place from 23rd August – 2nd September 2013, in Xiamen, China. This school will be held at the State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen, which is located on the Southeast coast of China. It is the first time for the school to be held out of Europe after 5 continuous successful schools in Cargese, Corsica, France.

Over 200 masters, PhD students and early stage researchers applied this year and the standard of applications, as ever, was very high. The summer school represents an invaluable opportunity for participants from around the world to learn more about the current understanding and recent advances in a wide range of SOLAS relevant research from world leading SOLAS scientists.

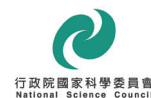
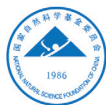
The success of the school depends on the dedication of the schools scientific organizing committee, lecturers, international project office, local organizers, and the generosity of sponsors worldwide. SOLAS would particularly like to thank the following for their commitment to the SOLAS Summer School 2013. SOLAS Summer School Scientific Organizing Committee: Emilie Brévière, Minhan Dai, Christoph Garbe, Véronique Garçon, Cliff Law, Maurice Levasseur, Peter Liss, Patricia Quinn, Eric Saltzman, Mitsuo Uematsu, Phil Williamson and Jeff Hare.

Warm thanks, goes to the local organizing committee, summer school directors, lecturers and demonstrators.

More information can be found at <http://mel.xmu.edu.cn/SOLASsummerschool>



## SOLAS Summer School 2013 sponsors as of June 2013



近海海洋环境科学国家重点实验室 (厦门大学)  
State Key Laboratory of Marine Environmental Science (Xiamen University)



surface ocean solas 2013 lower atmosphere study



## Second version of the Surface Ocean CO<sub>2</sub> Atlas (SOCAT) to be released this summer for climate research

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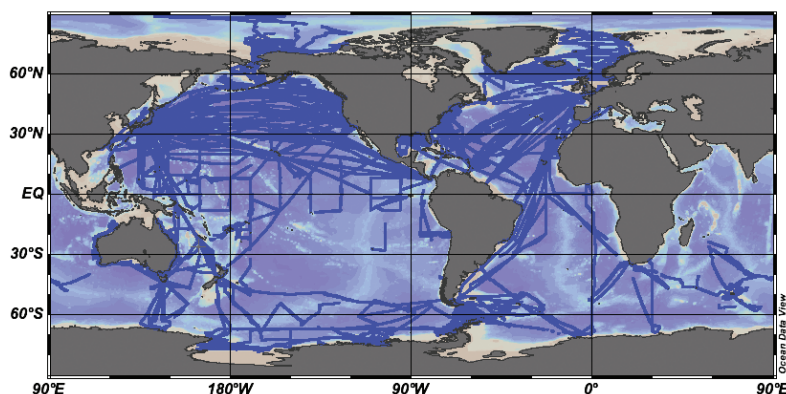
The second version of the Surface Ocean CO<sub>2</sub> Atlas has been assembled and is now distributed for testing among volunteers prior to the official release, which will take place during a special lunch session on the Tuesday of the 9th International Carbon Dioxide Conference in Beijing this summer (<http://www.ioccp.org/slides/11-slide-1>). SOCATv2 expands the first release of SOCAT by some four million fCO<sub>2</sub> data points, mostly from the four years 2008 through 2011, which brings the total number of fCO<sub>2</sub> data points up to above ten million, altogether covering the last four decades.

The assembly, quality control and distribution of SOCATv2 have largely been carried out by the same dedicated, large international team that released SOCATv1.5 two years ago. This team recently published two articles in the journal *Earth System Science Data* fully describing SOCATv1.5 (Pfeil et al., A uniform, quality controlled Surface Ocean CO<sub>2</sub> Atlas, *ESSD*, 5, 125-143, 2013) and the gridded product (Sabine et al., Surface Ocean CO<sub>2</sub> Atlas gridded data products, *ESSD*, 5, 145-153). However, some team members have become less

active in SOCAT and some new faces have appeared. We would here in particular acknowledge the coastal region leads for v1.5 Arthur Chen and Alberto Borges, the v1.5 equatorial Pacific lead Richard Feely, and the v1.5 global group member Chris Sabine. These have been replaced by Simone Alin, Burke Hales, Wei-Jun Cai (all coastal), Cathy Cosca (Equatorial Pacific), and Denis Pierrot (global), which we wholeheartedly welcome. In addition we welcome the leader for the recently conceived Arctic group, Jeremy Mathis.

The SOCAT team has now started preparations for SOCAT version 3, and we take this opportunity to fix a number of underlying issues with SOCAT and aim for a much more streamlined process. We would like to mention the ongoing effort towards an automated submission system, allowing contributors to submit their data and metadata online, a process that will include quality and conformation checks, which will relieve the SOCAT quality control team of some of its more tedious tasks. Further, a revised flagging scheme has been prepared by Rik Wanninkhof and colleagues, which is now available for community review through our home page at [www.SOCAT.info](http://www.SOCAT.info).

We appreciate all contributions to SOCAT, for example in the form of data product tests, data, software development and quality control. Please feel free to contact the authors if you would like to contribute.



▲ **Figure:** SOCATv2 includes more than ten million data, an increase of four million from the previous SOCAT release. Most of these new data are from the four years 2008 through 2011, and where obtained at the positions shown in this figure.



**Integrated Marine Biogeochemistry and  
Ecosystem Research**

IMBER aims to provide a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the Earth System and human society. IMBER research is organised along four themes: 'Interactions between Biogeochemical Cycles and Marine Food Webs'; 'Sensitivity to Global Change'; 'Feedbacks to Earth System'; and 'Responses of Society'.

Since summer 2012, IMBER has been very active. Here is a short selection of recent highlights and planned activities of potential interest to the SOLAS community:

1. The third ClimEco Summer School (July 2012, Turkey; [www.imber.info/index.php/Early-Career/IMBER-Summer-Schools/ClimECO3-July-2012-Ankara-Turkey](http://www.imber.info/index.php/Early-Career/IMBER-Summer-Schools/ClimECO3-July-2012-Ankara-Turkey)) titled 'A view towards integrated Earth System models. Human-nature interactions in the marine world' brought together 10 lecturers and 50 students / early career researchers, from 25 countries and various social and natural science backgrounds.
2. The IMBIZO III (Jan 2013, India; [www.imber.info/index.php/Meetings/IMBIZO/IMBIZO-III](http://www.imber.info/index.php/Meetings/IMBIZO/IMBIZO-III)) focused on 'The future of marine biogeochemistry, ecosystems and societies' and gathered 120 researchers and students from 30 countries. Two working groups met to further develop their activities and a workshop took place.
  - a. the IMBER-LOICZ 'Continental Margins Working Group' (CMWG) developing its strategic paper 'Living on the Margin in the Anthropocene: From Frontier to Engagement Arenas for Global Sustainability'.
  - b. the IMBER 'Human Dimensions Working Group' (HDWG) is developing the 'Assessment from Description, Appraisal and Typology' (ADApT) conceptual framework, a rapid integrated assessment and decision support tool to respond to global change in coastal regions.
  - c. the IMBER 'Data Management Training Course and Workshop' gathered about 50 participants. It aimed to enhance awareness of the need and benefit of establishing, early in the research process, good data management procedures as those outlined in the IMBER Data Management Cookbook ([www.imber.info/index.php/Science/Working-Groups/Data-Management/Cookbook](http://www.imber.info/index.php/Science/Working-Groups/Data-Management/Cookbook)).
3. The IMBER Open Science Conference 2014 (23-27 June 2014, Bergen, Norway; [www.imber.info/index.php/Meetings/IMBER-OSC-2014](http://www.imber.info/index.php/Meetings/IMBER-OSC-2014)) is under preparation. Its Call for abstracts will be open in the coming weeks.

Avril Bernard, IMBER Executive Officer  
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## SOLAS Canada

National Representative:

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It has been a busy year for Canadian SOLAS scientists with several accomplishments completed in the main research goals:

The ARCTIC-ICE program: The third ice camp took place during May-June 2012 in the Resolute Passage. The results highlighted higher DMS concentrations (up to 770nmol l<sup>-1</sup>) at the bottom of the ice and very short (min) turnover time of the dissolved DMSP reservoir. This suggests the presence of a high microbial activity in the brines.

The BaySys2012 is a continuing project investigating air-sea CO<sub>2</sub> exchange dynamics as high-pCO<sub>2</sub> river plumes mix with low-pCO<sub>2</sub> sea-ice melt-influenced marine water in Hudson Bay. The measurements were carried out to quantify the inorganic carbon system parameters in the surface waters at high vertical resolution.

A SABINA (Study of Air-Sea Biogeochemical Interactions in the North-western Atlantic) workshop was held in order to summarize the collected data during three cruises conducted in the North-western Atlantic. The workshop took place in Quebec, Canada and was sponsored by the Canadian Foundation for Climate and Atmospheric Sciences. Additionally, microcosms experiments were conducted in July 2012 to test the effect of pH on dimethylsulfide production by natural estuarine communities; these experiments showed that the local diatom community is resistant to pH changes.

Scientific highlight: Biological cycling of dimethylsulfoniopropionate (DMSP) and dimethylsulfide (DMS) in the Northwest Atlantic - Macroscale patterns and dynamics

The influence of the seasonal development of microplankton communities on the cycling of DMS and its precursor DMSP was investigated along a South-North gradient in the Northwest Atlantic. The South-North progression of the diatom bloom did not influence the production of DMS whereas conditions in the North Atlantic drift lead to a persistent bloom of DMSP-rich flagellate-dominated phytoplankton community and high net DMS production rates.

Lizotte M, Levasseur M, Michaud S, Scarratt MG, Merzouk A, Gosselin M, Pommier J, Rivkin RB, Kiene RP (2012). Biological cycling of dimethylsulfoniopropionate (DMSP) and dimethylsulfide (DMS) in the Northwest Atlantic - Macroscale patterns and dynamics. Biogeochemistry. doi: 10.1007/s10533-011-9698-4.



Since January 2011 Peter Landschützer is studying for a PhD degree at the University of East Anglia in Norwich, UK, funded by the European Union Marie Curie Greencycles II program. His research focuses on the seasonal to inter-annual variability of air-sea fluxes of carbon dioxide (CO<sub>2</sub>) in the Atlantic Ocean.

## The changing carbon sink in the Atlantic Ocean

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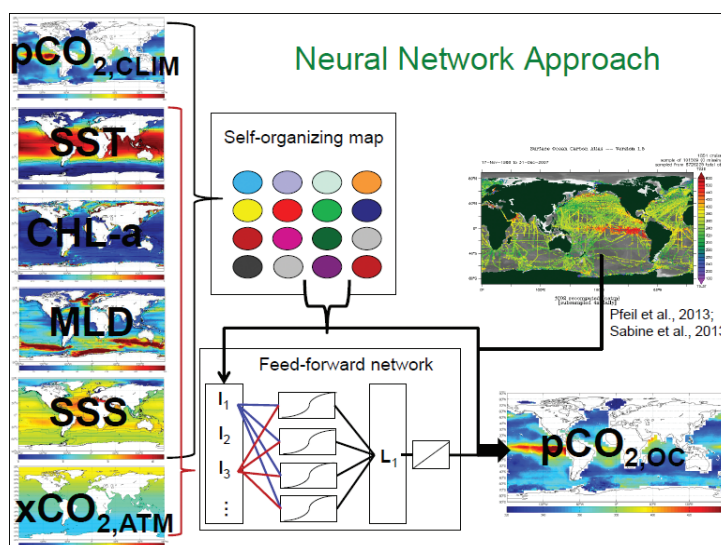
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The North Atlantic is playing a key role in the uptake of carbon dioxide (CO<sub>2</sub>) from the atmosphere. A recent estimate of the average basin-wide uptake of CO<sub>2</sub> was 0.49±0.11 PgC yr<sup>-1</sup> over the last two decades (Schuster et al., 2013), which accounts for 20-25% of the estimated global CO<sub>2</sub> uptake by the ocean based on model studies (Le Quéré et al., 2009), yet major uncertainties remain regarding long term basin-wide trends and the inter-annual variability of the basin's carbon sink. Therefore, since 2002, the University of East Anglia is measuring sea surface pCO<sub>2</sub> in the North Atlantic on-board commercial

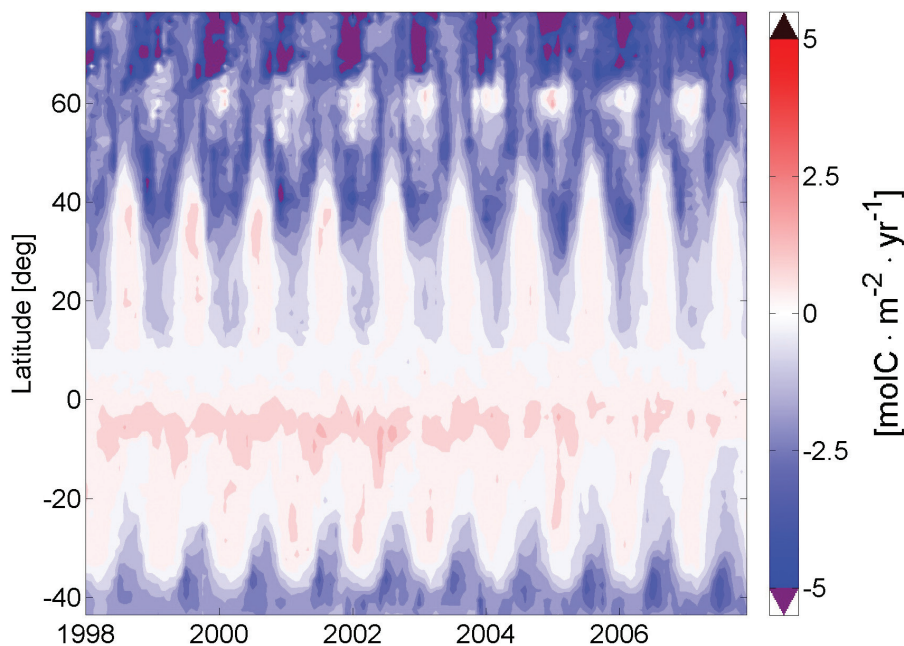
vessels between the UK and the Caribbean. These underway measurements are part of a collection of observations within the recently released SOCAT v1.5 database (Pfeil et al., 2013) which was made possible due to the data collection and synthesis effort of the marine carbon community. Basin-wide estimates of the sea surface pCO<sub>2</sub> based on observations, however, remain a key challenge, due to the highly heterogeneous distribution of the observations in time and space.

Here, we use a combination of two neural network methods to overcome this challenge (Figure 1): firstly, a self-organizing



**Figure 1:** Schematic of the two neural network steps. We firstly use a set of input parameters to identify 16 oceanic provinces, and secondly reconstruct the non-linear relationship between a second set of inputs and available gridded observations from the SOCAT V1.5 database (Pfeil et al., 2013; Sabine et al. 2013).





▲ **Figure 2:** Hovmöller diagram of the long term mean seasonal cycle of the CO<sub>2</sub> flux density in the Atlantic Ocean from 1998 to 2007. Negative values indicate a sink.

map to identify oceanic biogeochemical regions of similar input relations and secondly a feed-forward neural network to retrieve a continuous number of pCO<sub>2</sub> outputs. The second step reconstructs the relationship between sea surface temperature, chlorophyll-a concentration, mixed layer depth, sea surface salinity and atmospheric CO<sub>2</sub> and the co-located gridded observations from the SOCAT database (Sabine et al., 2013). We estimate monthly sea surface pCO<sub>2</sub> on a 1°x1° degree grid from 1998 to 2007, and compute air-sea CO<sub>2</sub> flux densities using a standard gas exchange parameterization and high-resolution wind speeds.

On basin scale our results (Landschützer et al., in prep.) are in good accordance with recent findings from Schuster et al. (2013). We find the strongest seasonal variability of the sea surface pCO<sub>2</sub> and the air-sea fluxes within the subtropics in the northern and southern hemisphere, i.e. the zones where the seasonal cycle of the sea surface pCO<sub>2</sub> is thermally driven (Figure 2). Trends in the sea surface pCO<sub>2</sub> suggest that in large areas polewards of 40°N the sea surface pCO<sub>2</sub> increased faster than the atmospheric pCO<sub>2</sub>. Basin-wide, however, the North Atlantic carbon sink was barely changing within the study period, whereas we find an increase in the South Atlantic carbon sink.

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## Acknowledgements

P. Landschützer acknowledges support by EU grant 238366 (GREENCYCLESII)



For more than 22 years, the North Pacific Marine Science Organization (PICES) has been providing an international forum for scientists from North America and Asia to tackle the complexities of natural and anthropogenic variability in the North Pacific Ocean. The PICES expert group on Carbon and Climate seized upon that opportunity to develop an integrated, intercalibrated, quality controlled database of carbonate system observations in the North Pacific. Public release of its major product, the PACIFICA database, is expected in May 2013.

PICES is anticipating an Open Science Meeting (OSM) for its integrative scientific program FUTURE (Forecasting and Understanding Trends, Uncertainty, and Responses of marine Ecosystems) from April 15-18, 2014 on the Kohala Coast, Hawaii. The overarching vision of the program is to understand and forecast responses of North Pacific marine ecosystems to climate change and human activities at basin and regional scales, and to broadly communicate this scientific information to members, governments, resource managers, stakeholders and the public. The OSM is an opportunity for a review of progress and to make necessary course corrections for the five years that remain of the program.

The PICES 2013 Summer School on Ocean Observing Systems and Ecosystem Monitoring (August 19-23, Newport, Oregon) is being organized in conjunction with Oregon State University. The school will provide hands-on at-sea training with new ocean monitoring technologies (e.g. gliders and profiling floats) and the remarkable data they are providing. It is proving to be a popular topic because the registrar received more than twice the number of applicants than could be accommodated.

Finally, at PICES 2013 annual meeting (October 16, Nanaimo, Canada) SOLAS and PICES are teaming up to offer a Topic Session on The changing carbon cycle of North Pacific continental shelves and marginal seas, co-venued by Minhan Dai (China), Sophia Johannessen (Canada), and Dong-Jin Kang (Korea), with Miguel Goni (Oregon State University, USA), and Kon-Ke Liu

(Institute of Hydrological and Oceanic Sciences, National Central University, China-Taipei) as invited speakers. Early registration and abstract submission deadlines are June 30, 2013 (<http://www.pices.int/meetings/annual/PICES-2013/2013-background.aspx>). PICES is the organization for international interdisciplinary research directed at understanding marine ecosystems of the North Pacific.

Skip McKinnell, Deputy Executive Secretary ([mckinnell@pices.int](mailto:mckinnell@pices.int)) [www.pices.int](http://www.pices.int)



### SOLAS Korea

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As part of the East Asian Seas Time-series-1 project, a research expedition took place in the East/Japan Sea in the western temperate North Pacific on board the Russia R/V Akademik Oparin in October 2012. The western North Pacific is an excellent site for investigating temporal trends in oceanic uptake of anthropogenic CO<sub>2</sub>. The data was collected from 43 hydrographic stations and included salinity, temperature, oxygen and nutrient concentrations were measured. Concentrations of total dissolved inorganic carbon and total alkalinity were determined at 25 of these stations.

An interesting international collaboration was established between the Pohang University of Science and Technology in Korea and Dr. Jim Murray (experiment leader), University of Washington (Seattle, USA). A group of Korean scientists participated in a 3-week ocean acidification experiment at the Friday Harbour Laboratories in April 2013.

Scientific highlight: Shifts in biogenic carbon flow from particulate to dissolved forms under high carbon dioxide and warm ocean conditions

Mesocosm experiments were carried out in order to investigate the potential effects of ocean acidification and warming on the biological carbon pump. The elevated CO<sub>2</sub> and temperature treatments disproportionately enhanced the ratio of dissolved organic carbon (DOC) to particulate organic carbon production. The total organic carbon production remained relatively constant under all tested conditions.

Further studies that took place in 2012 concentrated on the spatial variation of the longitudinal dispersion coefficient in the Sumjin River Estuary, heterotrophic feeding identification as a new survival strategy of the dinoflagellate *Symbiodinium*, and on the accumulation of galloyl derivatives in a freshwater green alga, *Spirogyra* variants, in response to cold stress.

Kim, J.M., Lee, K., Shin, S., Yang, E.J., Engel, A., Karl, D. M., Kim, H.-C. (2011). Shifts in biogenic carbon flow from particulate to dissolved forms under high carbon dioxide and warm ocean conditions. *Geophysical Research Letters*, 38, doi:10.1029/2011GL047346



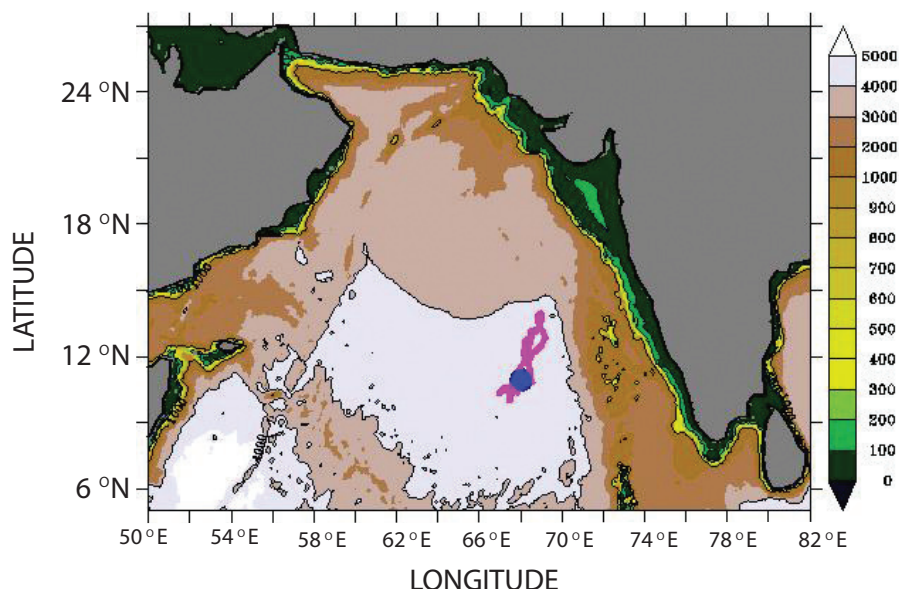
Ravichandran is a Senior Scientist, heading the modeling and observation group at INCOIS. He is currently a member of International Argo Steering Team (IAST), Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) and a co-chair of Indian Ocean Panel (CLIVAR/GOOS).

Satya Prakash is a scientist at INCOIS. He obtained his PhD on biogeochemistry of the Indian Ocean. His research interest is the use autonomous floats to understand bio-physical and biogeochemical interactions in the Northern Indian Ocean.

## Autonomous floats provide new insights of Biogeochemistry in the Arabian Sea

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Contact: ravi@incois.gov.in



▲ Figure 1: Deployment location (shown as blue dot) and trajectory (shown in pink color) of Bio-Argo float in the Arabian Sea. The shading represents bathymetry of the Arabian Sea using ETOPO2 bathymetry data from NOAA National Geophysical Data Center (NGDC) (2006); color bar shows depth in meter.

Development of new observation systems either satellite based or *in-situ* has provided tremendous opportunity to understand ocean around us at enhanced temporal and spatial scales. These observation systems not only helped to understand the governing processes but also enabled us to quantify the effect of anthropogenic perturbations in climate studies. Implementation of the Argo programme allowed us to overcome the limitation of satellite oceanography by making interior of the ocean accessible to the scientific community. New generation Argo floats equipped with optical sensors

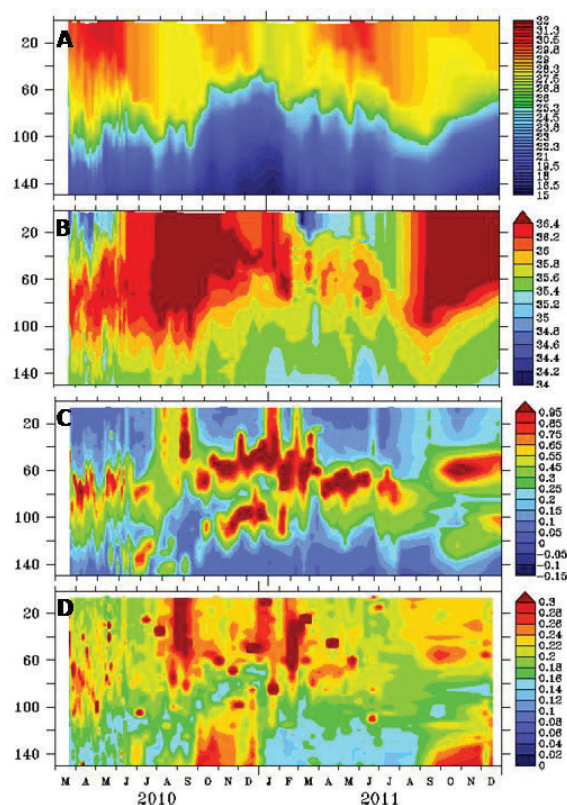
enabled collection of biogeochemical data and their interpretation in the context of physical and dynamic variability. It has, therefore, got tremendous potential to develop a better understanding of ocean's bio-physical interaction and its role in climate change.

Indian National Centre for Ocean Information Services (INCOIS), a regional Argo data centre, is actively involved in the international Argo programme and has deployed Argo floats equipped with optical sensors in the Indian Ocean. The



northern Indian Ocean is a unique tropical basin which is forced by seasonally reversing monsoon winds. It profoundly influences circulation and thermohaline structure and, thereby alters its biogeochemical characteristics. For the above said reason it hosts a wide range of biogeochemical provinces such as highly productive Arabian Sea, oligotrophic equatorial Indian Ocean and relatively low productive Bay of Bengal and have significant seasonal variability in terms of biogeochemical cycling of key elements. This basin also experiences severe oxygen depletion at the sub-surface layer (~150-1000 m depth) and is characterized by one of the highest volumes of suboxic ( $< 5 \mu\text{mol kg}^{-1}$ ) waters. Argo floats, equipped with sensor for measuring dissolved oxygen in the water (e.g., WMO ID 2900776) provide a better insight into the seasonality of oxycline. This seasonality was not observed during the Joint Global Ocean Flux Study (JGOFS) probably because of limitation in analytical techniques. The observed seasonality (i.e., shallowing and deepening) in the depth of oxycline is associated with similar seasonality in the thermocline. An analysis of Satellite derived Sea Surface Height Anomaly data indicate towards a possible role of large scale planetary waves such as westward propagating Rossby waves in modulating the depth of thermocline and, thus the oxycline (Ravichandran et al., 2012 and Prakash et al., 2012a).

One more float, equipped with sensors for chlorophyll and backscattering (serves as a proxy for the amount of suspended matter in seawater) along with traditional CTD was deployed in the South eastern Arabian Sea. The Argo chlorophyll data compares well with MODIS chlorophyll data and therefore provides confidence in float based measurement. The vertical distribution of chlorophyll from the float based measurement, a major limitation of satellite based measurements, shows persistent occurrence of sub-surface chlorophyll maxima. The float data suggests that sub-surface chlorophyll maxima always occurs above the permanent thermocline and oxycline depths. It also shows that westward propagating Rossby waves significantly influences the depth of sub-surface chlorophyll maxima by altering the depth of the thermocline; the thermocline and nutricline co-varies in the Arabian Sea



▲ Figure 2: Depth-time section of (A) Temperature, (B) Salinity, (C) chlorophyll-a ( $\text{mg m}^{-3}$ ) and (D) particulate backscattering at 700 nm ( $10^{-3} \text{ m}^{-1}$ ) from a Bio-Argo float deployed in the southeastern Arabian Sea.

(Prakash et al., 2012b) and therefore any variation in thermocline bound to have an effect on nutricline and thus on the depth of chlorophyll maxima. The float data also indicates toward presence of a secondary fluorescence maxima below oxycline and euphotic depths (~140 m) which may be due to presence of *Prochlorococcus*. Earlier *in-situ* observations have also suggested presence of this species in the lower euphotic zones of subtropical and tropical ocean waters. Further, the analysis of float based chlorophyll data helped to explain the mechanism of occurrence of summer bloom in surface waters of this basin. During the initial period of the summer monsoon, sudden deepening of the mixed layer causes entrainment of sub-surface chlorophyll maxima into the mixed layer which causes bloom in the surface layer (Ravichandran et al., 2012).

These studies highlight utility of bio-Argo floats to study and understand the biophysical dynamics of the basin on increasing temporal and vertical resolutions. More

deployment of such sensors/floats is bound to have revolutionizing effects on oceanographic studies especially those pertaining to biogeochemical cycling of elements.

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Kai Lohbeck is a PhD student in the BIOACID project at GEOMAR (Kiel, Germany). His interdisciplinary work combines biological oceanography and evolutionary biology to investigate the potential for evolutionary adaptation to ocean acidification in marine phytoplankton.

## Marine phytoplankton can adapt to ocean acidification

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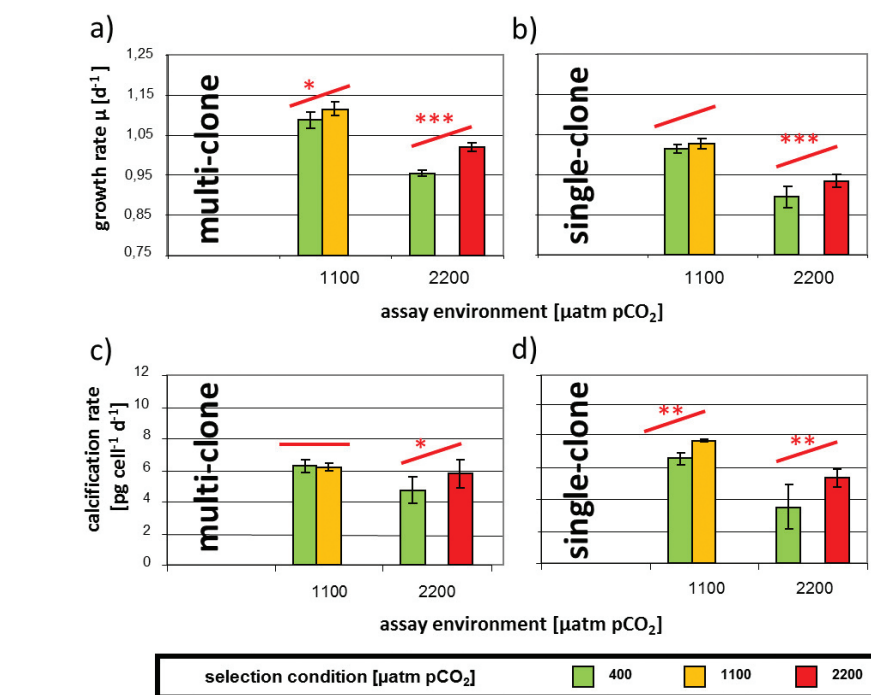
Contact: klobeck@geomar.de

The uptake of fossil fuel-derived carbon dioxide by the surface ocean alters seawater carbonate chemistry and results in a drop in ocean pH (Caldeira and Wickett 2003). These changes, dubbed ocean acidification, have a severe impact on many marine organisms, especially those that build their cell walls, shells, scales or skeletons from calcium carbonate (Orr et al., 2005).

Coccolithophores, a group of planktonic microalgae that are among the most productive calcifying organisms in the sea (Westbroek et al., 1989), were found to be sensitive to ocean acidification with most studies showing a decline in growth and calcification rate at increased CO<sub>2</sub> levels (Riebesell and Tortell 2011).

Such studies have usually been short term (a couple of weeks) and none tested for evolutionary adaptation, a major unknown when attempting to predict future impacts of ocean acidification on marine life (Riebesell et al., 2009). As coccolithophore populations reproduce quickly and have large population sizes, they should be particularly prone to respond to ocean change via adaptive evolution (Bell and Collins 2008).

To test whether marine phytoplankton can adapt to ocean acidification, we conducted two long-term laboratory selection experiments where we exposed replicate populations of the coccolithophore *Emiliania huxleyi* for about one year to elevated CO<sub>2</sub> levels. One experiment started from replicated populations assembled from equal contributions of six different clones and the other from replicates originating from a single clone. The multi-clone experiment was designed to provide standing genetic variation that would allow population-level adaptation by genotypic selection, whereas in the single-clone experiment adaptation requires new mutations (Lohbeck et al., 2012).



▲ Figure 1: Phenotypic responses after ~500 generations of CO<sub>2</sub> selection in *Emiliania huxleyi*. Replicate cultures (n=5) were initially either founded by six clones (left panels) or a single clone (right panels). a,b, Mean exponential growth rate. c,d, Mean production rate of particulate inorganic carbon/calcification rate (\*P≤0.05; \*\*P≤0.01; \*\*\*P≤0.001; error bars ±1 s.d.).

Replicate selection lines were grown for about 500 asexual generations at ambient (400 μatm), medium (1100 μatm) and high (2200 μatm) levels of CO<sub>2</sub> partial pressure. The medium-CO<sub>2</sub> treatment represented a level projected for the beginning of the next century while the highest level served as a proof of principle, representing a sufficiently strong selective force. To test for adaptation we then compared populations grown under increased CO<sub>2</sub> levels with those kept under ambient CO<sub>2</sub> levels in an increased CO<sub>2</sub> assay environment (Lohbeck et al., 2012).

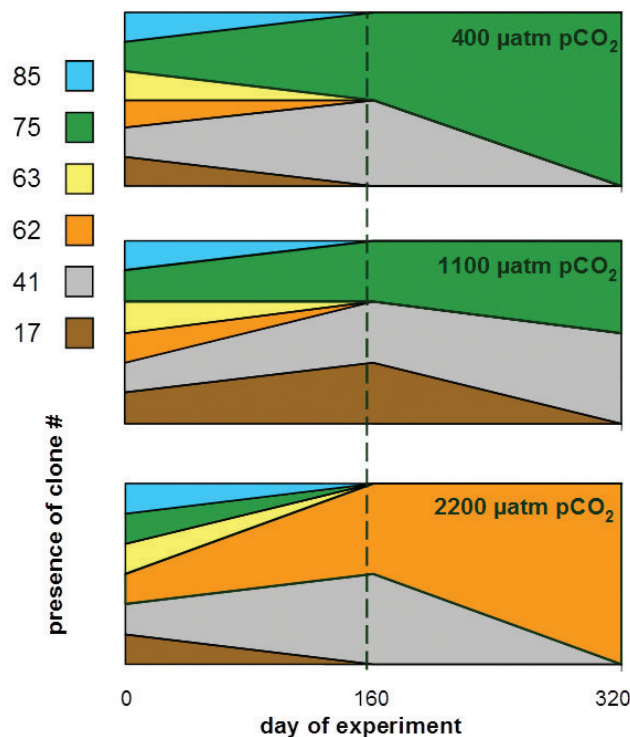
Our study identified direct, positive adaptation to increased CO<sub>2</sub> levels in a calcifying marine phytoplankton species. In both experiments, *E. huxleyi* populations adapted to elevated CO<sub>2</sub> conditions and showed significantly increased exponential

growth rates (a direct measure of Darwinian fitness) and partly restored calcification rates relative to control populations when tested under ocean acidification conditions (Fig. 1). In the multi-clone experiment the presence of the six experimental clones throughout the experiment was examined using microsatellite genotyping. The genotypic composition of the populations diverged consistently among treatments (Fig. 2).

We identified genotypic selection as one immediate mechanism of population-level adaptation in the multi-clone experiment. The adaptive response observed in the single-clone experiment suggests a contribution of advantageous new mutations.

Coccolithophores play an important role in ocean productivity and the marine carbon





▲ **Figure 2:** Time course of the presence of *Emiliana huxleyi* clones in the multi-clone experiment. All three CO<sub>2</sub> treatments started with the same assemblage of six clones. The presence of individual clones was assessed by polymerase chain reaction of diagnostic alleles at five microsatellite marker loci.

cycle (Westbroek et al., 1989). Hence, the swift adaptation processes observed here have the potential to affect food-web dynamics and biogeochemical cycles on climate change-relevant timescales. Our findings emphasize the need to consider evolutionary processes in future studies on the biological consequences of global change.

As experimental evolution experiments reveal only the potential for adaptation, they need to be further scrutinized against field observations to assess to what extent evolutionary changes observed under laboratory conditions apply in the oceans, where other environmental factors and ecological interactions play along.

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## Acknowledgements

This work was funded by the German Federal Ministry of Education and Research (BMBF).

## Outcome of the IGBP/SCOR Fast Track Initiative on 'Megacities and the Coastal Zone: air-sea interactions'

Megacities and large urban agglomerations are usually defined as having more than 10 million inhabitants and are characterised by a particularly high population density. More than 10% of the world's population live in megacities, and this proportion is expected to increase in coming decades. Even though a very large number of megacities are located at the coast, there has not been a systematic consideration of the additional pressures and effects that the location of this juxtaposition of land and ocean has.

To address this, a SOLAS/IGAC/LOICZ fast track initiative held a workshop in Norwich in April 2010 sponsored by IGBP/SCOR. The attending scientists had expertise in various aspects of atmospheric and marine physics and chemistry as well as in marine biology. The focus of the workshop was on the physical and biogeochemical interactions between the atmosphere, the land and the ocean in and around coastal megacities. These relate to air and water quality as well as regional climate and hence directly affect human wellbeing. In the workshop we were able to identify what we believe to be the following most important environmental issues: Effects on the self-cleansing capability of the atmosphere (in the megacity and its outflow); Greenhouse gases: sources, atmospheric lifetime; Pollution and health; Coastal eutrophication and resulting effects including on fisheries; Atmospheric circulation/mixing; Hydrological cycle; Radiative forcing caused by the Megacities in the Coastal Zone.

The outcomes of this workshop have now been published: von Glasow et al, "Megacities and Large Urban Agglomerations in the Coastal Zone: Interactions Between Atmosphere, Land, and Marine Ecosystems", *AMBIO* 2013, 42:13–28, DOI 10.1007/s13280-012-0343-9.

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# Ocean Acidification International Coordination Centre

L. Hansson

Ocean Acidification International Coordination Centre (OA-ICC), Monaco



Ocean Acidification  
International  
Coordination Centre  
**OA-ICC**

Within less than a decade, ocean acidification has gone from a science without a label involving few scientists to a research topic studied by many hundreds that is considered the #1 research front in Ecology and Environmental Sciences (King and Pendlebury, 2013)<sup>1</sup>. As research activities on ocean acidification continue to develop, there is a growing need for international collaboration and coordination.

In recent years, EPOCA<sup>2</sup>, the first multi-national project on ocean acidification, partly filled this need. This 4-year European project ended in 2012. Recognizing the need to continue and develop international activities, the SOLAS-IMBER joint Working Group on Ocean Acidification (SIOA) and the Ocean Acidification International Reference Users Group (OA-iRUG) called for an international effort to coordinate, promote and facilitate science and related activities.

Responding to this call and to the increasing concern about ocean acidification from many of its Member States and international organizations, the International Atomic Energy Agency (IAEA) stepped in and announced a new project, the "Ocean Acidification International Coordination Centre (OA-ICC)", at the UN Conference on Sustainable Development (Rio+20) in June 2012. The OA-ICC is supported by direct and in-kind contributions from 8 IAEA Member States (Australia, France, Italy, New Zealand, Norway, Spain, UK and USA) via the IAEA Peaceful Uses Initiative (PUI), and cooperates with the major programmes in the field of ocean acidification (e.g., SOLAS



▲ Photo: Example of international collaboration on ocean acidification: mesocosm facilities developed at the Helmholtz Centre for Ocean Research Kiel and used during a field campaign of the European Project on Ocean Acidification (EPOCA) in Svalbard, summer 2010. The experiment involved 40 scientists from 10 institutes. Photo: Nick Cobbing

and IMBER, IOCCP<sup>3</sup>, BIOACID<sup>4</sup>, UKOA<sup>5</sup>, MedSeA<sup>6</sup> and NOAA-OAP<sup>7</sup>). The OA-ICC is based in Monaco at the IAEA's Environment Laboratories. It is currently funded for 3 years with goals to foster scientific collaboration at the international level, promote best practices, improve observational capacities and databases, and facilitate communication and outreach.

The OA-ICC is promoting a series of overarching international activities to serve not only the scientific community but also science users, including policy makers, media, and the general public. Recent and on-going OA-ICC activities include (1) helping to run an international exhibition stand that highlighted ocean acidification at the UNFCCC COP18 in Doha, (2) running an exercise to compare seven publicly available packages that compute marine carbonate chemistry, (3) helping support the Second Global Ocean Acidification Observation Network workshop (St. Andrews, 24-26 Jul 2013) and (4) supporting the 6th SOLAS

summer school (Xiamen, 26 Aug-2 Sep 2013). Further details about these and other OA-ICC activities are available on the OA-ICC web site.

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<sup>1</sup>King C. & Pendlebury D. A., 2013. Research Fronts 2013: 100 top-ranked specialties in the sciences and social sciences. 32 p. Thomson Reuters.

<sup>2</sup>European Project on Ocean Acidification

<sup>3</sup>International Ocean Carbon Coordination Project

<sup>4</sup>Biological Impacts of Ocean Acidification

<sup>5</sup>UK Ocean Acidification Research Programme

<sup>6</sup>Mediterranean Sea Acidification in a Changing Climate

<sup>7</sup>US National Oceanic and Atmospheric Administration Ocean Acidification Program

## SOLAS Metadata Portal

**What and where are the available data that the SOLAS community collected?**

**How can you contribute to the collection with the SOLAS-relevant data you have collected?**

Visit the SOLAS Metadata Portal at <http://tinyurl.com/46xnf9>, a resource freely-available to the entire community.

The SOLAS Metadata portal is an ongoing effort, initiated through the SOLAS Integration project. The portal lists what SOLAS data exists and where it is archived, along with information such as where and when it was collected and the name of the data-provider. You can also help expanding the SOLAS meta-database by completing the simple template form available at <http://tinyurl.com/328zjr5> and email it to [solas@geomar.de](mailto:solas@geomar.de)





Barbara Jacob is currently a post-doctoral associate at the Aquatic Ecosystem Functioning Lab (LAFE) under the sponsorship of Dr. Cristian A. Vargas at the Environmental Science Center EULA Chile (Universidad de Concepción), Chile. Her research is focused on understanding the effects of ocean acidification on natural phytoplankton communities as well as on key algal species (flagellates vs. diatom species).

## Effects of ocean acidification on phytoplankton in upwelling areas influenced by river discharges

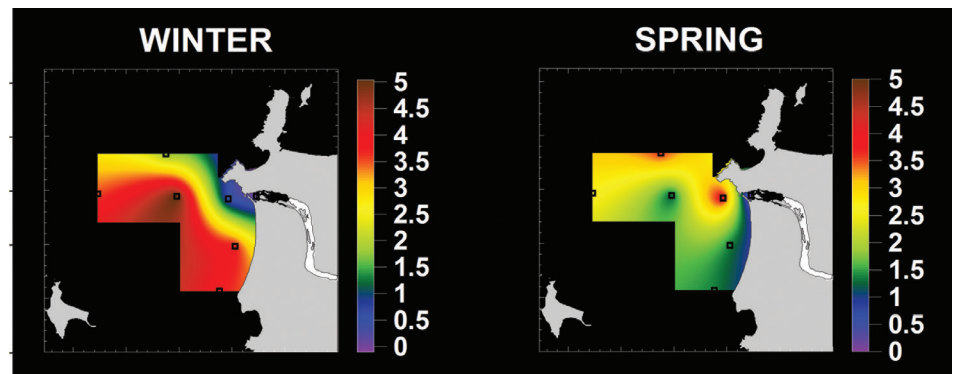
B. Jacob and C. A. Vargas

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About 48% of carbon dioxide released to the atmosphere in the last 200 years has been caused by man (Raven et al., 2005). The oceans have absorbed nearly half of the fossil-fuel carbon dioxide ( $\text{CO}_2$ ) emitted into the atmosphere since pre-industrial times. This capacity causes the reduction in seawater pH and carbonate saturation, a process known as "ocean acidification". Studies of the effect of ocean acidification on phytoplankton suggest that increasing the concentration of  $\text{CO}_2$  may stimulate phytoplankton growth rate or efficiency of resource utilization and hence alter the species composition of phytoplankton communities. Recent studies have shown effects of ocean acidification increases the dissolved inorganic carbon consumption of a natural plankton community with rising  $\text{CO}_2$  (Riebesell et al., 2007). Stoichiometric changes in the C:N ratio of the primary production to high  $\text{pCO}_2$  levels may affect the availability of labile carbon that could be used by heterotrophic microbial community, in terms of their utilization of the mineral nutrients, which in turn, can limit the primary production due to the reduction of mineral nutrients.

The Humboldt Current System (HCS) is the second most productive eastern boundary current after the Benguela Upwelling Ecosystem (Monteiro 2010). The HCS has shown variability in the  $\text{pCO}_2$  concentrations due to the  $\text{CO}_2$  sequestration by photosynthesis and the degassing associated with the upwelling of cold, oxygen-poor and strongly super-saturated  $\text{CO}_2$ . And thus, the biological pump interacts with the physical processes promoting the exchange of  $\text{CO}_2$  in the ocean-atmosphere interface (Torres et al., 2002). Moreover, these ecosystems are affected by persistent or episodic input of acid water from rivers. The figure 1 shows the coastal upwelling ecosystem close to the Biobío river mouth, in the central-south of Chile. In this area, the favourable winds



▲ Figure: Seasonal variability of saturation state of Aragonite ( $\Omega_{\text{Ar}}$ ) in the coastal upwelling ecosystem close to the Bio Bio river mouth, in the central-south of Chile. If  $\Omega_{\text{Ar}} > 1$ , the seawater is supersaturated with respect to Aragonite; if  $\Omega_{\text{Ar}} < 1$ , the seawater is undersaturated with respect to Aragonite (Preliminary results from RIVOM Project by C.A. Vargas and B. Jacob).

to the upwelling are present during the spring-summer seasons while, during winter the river freshwater discharges increase. Strong gradients and seasonal variability in the saturation state of the Aragonite ( $\Omega_{\text{Ar}}$ ) have been observed in the vicinity areas influenced by the Biobío river discharges in this region. During winter period, more acidic and under-saturated with respect to Aragonite waters reached a major longitudinal extension in the studied area, which suggests that regional changes in the carbonate chemical system depends on the interplay between the freshwater river inputs and the upwelling regime.

The main objective of this research is to determine - through field studies and laboratory controlled experimental conditions- the effect of the coastal ocean environmental variability on phytoplankton, in terms of changes in the carbonate system parameters influenced either naturally by river discharge or coastal upwelling. For this purpose, experiments will be designed to represent projections of the future carbonate system and assess the natural response of the key phytoplankton species (diatoms and flagellates), as well as natural phytoplankton communities from different environments.

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### Acknowledgements

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# Meteor cruise M91 to the coastal upwelling off Peru

H. W. Bange and the team of M91  
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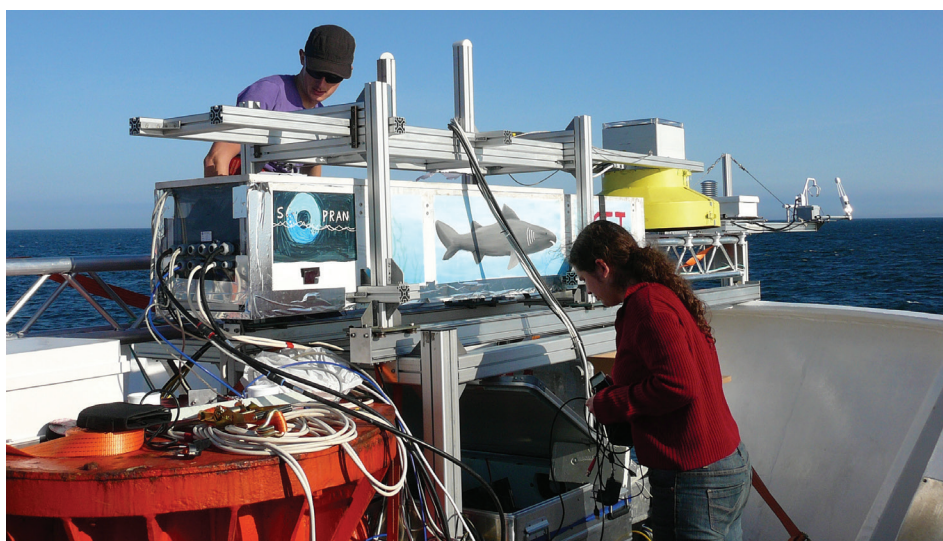
The R/V Meteor Cruise M91 to the upwelling off Peru took place from 1st to 26th December of 2012 (Figure 1). 24 scientists from various SOPRAN subprojects as well as three scientists from the Instituto del Mar del Perú (IMARPE, Callao, Peru) and two scientists from the Joint Collaborative Centre SFB754 (Kiel) took part in the cruise. The overall goal of M91 was to conduct an integrated biogeochemical study on the upwelling region off Peru in order to assess its importance for the emissions of various climate-relevant atmospheric trace gases and tropospheric chemistry. The major objectives were (i) to estimate the emissions of trace gases such as nitrous oxide ( $\text{N}_2\text{O}$ ), carbon dioxide ( $\text{CO}_2$ ), halocarbons, DMS, VOCs and other trace gases from and the deposition of aerosols to the Peruvian upwelling region, (ii) to investigate the role of the seasurface microlayer for the exchange of trace gases across the ocean/atmosphere interface and (iii) to investigate the role of the coastal upwelling and the underlying oxygen minimum zone off Peru as a source of trace gases. The various work packages of M91 included in-situ measurements of and sampling for atmospheric and dissolved trace gases, aerosols, nitrogen processes and isotopes in the water column, dissolved organic matter in the surface microlayer, upwelling velocity and exchange fluxes across the ocean/atmosphere interface (Figure 2).

Eight transects perpendicular to the Peruvian coast located between 5°S and 16°S have been sampled (A-E, G, I-J), see Figure 1.

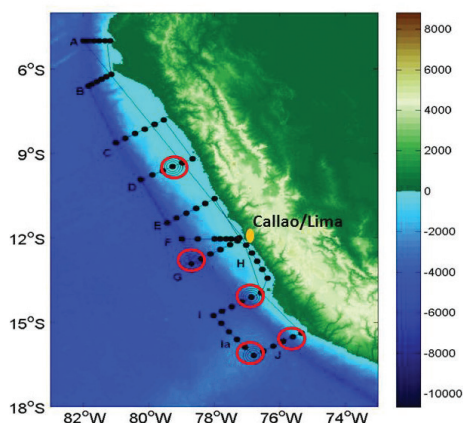
They were identical to the regularly occupied oceanographic sampling lines of IMARPE and cover the major upwelling centres along the coast off Peru. In addition we sampled the coastal time series stations off Callao (transect F) and a transect parallel to the Peruvian coast south of Callao (transect H). Transect H was chosen to sample the region where an anoxic event during the Meteor cruise M77/3 (Dec. 2008/January 2009) has been observed. Moreover five 24h stations, where the ship stayed at one position from 24h, were performed. In total 123 radiosonde launches (Figure 3), 98 CTD/Rosette stations, 55 microstructure casts and 45 sampling trips with a zodiac were performed (Figure 4). Moreover, continuous underway atmospheric and surface

ocean sampling and measurements were performed along the entire cruise track.

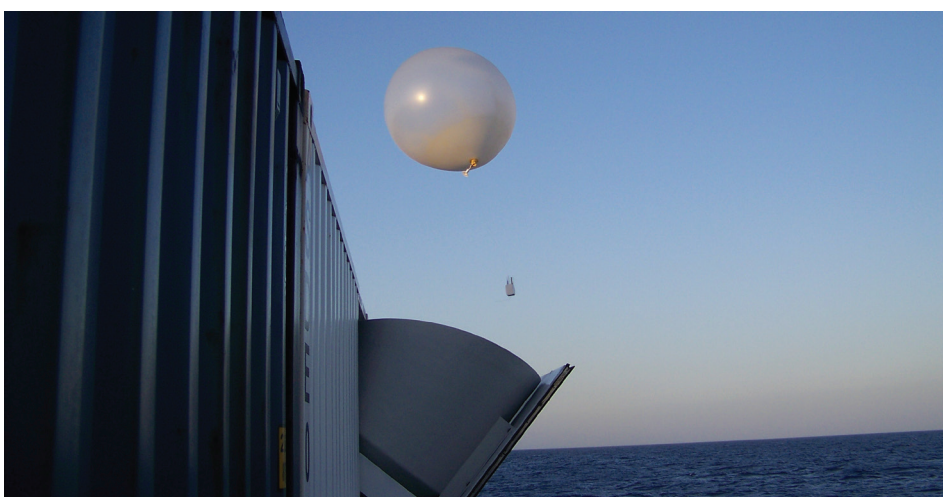
M91 is a joint effort of GEOMAR (Kiel), DWD (Hamburg), IOW (Warnemünde), IMARPE (Callao, Peru), LDEO (Palisades, NY), MPI for Chemistry (Mainz), RSMAS (Miami, FL), TUB (Braunschweig), U Bremen, UEA (Norwich, UK), U Hamburg, U Heidelberg, U Kiel, and U Massachusetts (Dartmouth, MA). M91 is contribution to the SOLAS Mid-Term Strategy initiative "Air-sea gas fluxes at eastern boundary upwelling and oxygen minimum zones system" and was funded by SOPRAN (Surface Ocean Processes in the Anthropocene) through BMBF grant # FKZ03F0611A.



▲ Figure 2: Leila Nagel and Daniel Kiefhaber (both from U Heidelberg) are working on the instrument package for flux measurements mounted at the bow of Meteor.



▲ Figure 1: Cruise track with locations of stations (black dots) of M91. Transects A-J are indicated as well as the locations of the 24h station (red circles).



▲ Figure 3: Launch of a radiosonde from Meteor (picture © DWD).



## Conference Calendar

Dates	Conference	Location
04.08.2013 - 09.08.2013	2013 Gordon Research Conference on Chemical Oceanography	Maine, USA
19.08.2013 - 23.08.2013	PICES 2013 Summer School on Ocean Observing and Ecosystem Monitoring	Oregon, USA
23.08.2013 - 02.09.2013	SOLAS Summer School 2013	Xiamen, China
01.09.2013 - 06.09.2013	11th International Conference on Paleoceanography	Barcelona, Spain
24.09.2013 - 27.09.2013	Air-sea Gas Flux Climatology; Progress and Future Prospects Workshop	Brest, France
30.09.2013 - 01.10.2013	Sea Spray Aerosol Workshop (OSSA)	Galway, Ireland
09.09.2013 - 13.09.2013	The ESA Living Planet Symposium	Edinburgh, UK
06.11.2013 - 08.11.2013	EUR-OCEANS hot topics conference - A changing ocean	Gran Canaria, Spain
23.02.2014 - 28.02.2014	2014 Ocean Sciences Meeting	Hawaii, USA
15.04.2014 - 18.04.2014	PICES Open Science Meeting	Hawaii, USA
19.05.2014 - 23.05.2014	6th International Symposium on biological and environmental chemistry of DMS(P) and related compounds	Barcelona, Spain
23.06.2014 - 27.06.2014	IMBER Open Science Conference	Bergen, Norway

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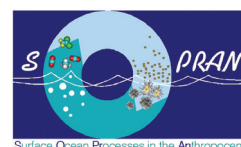
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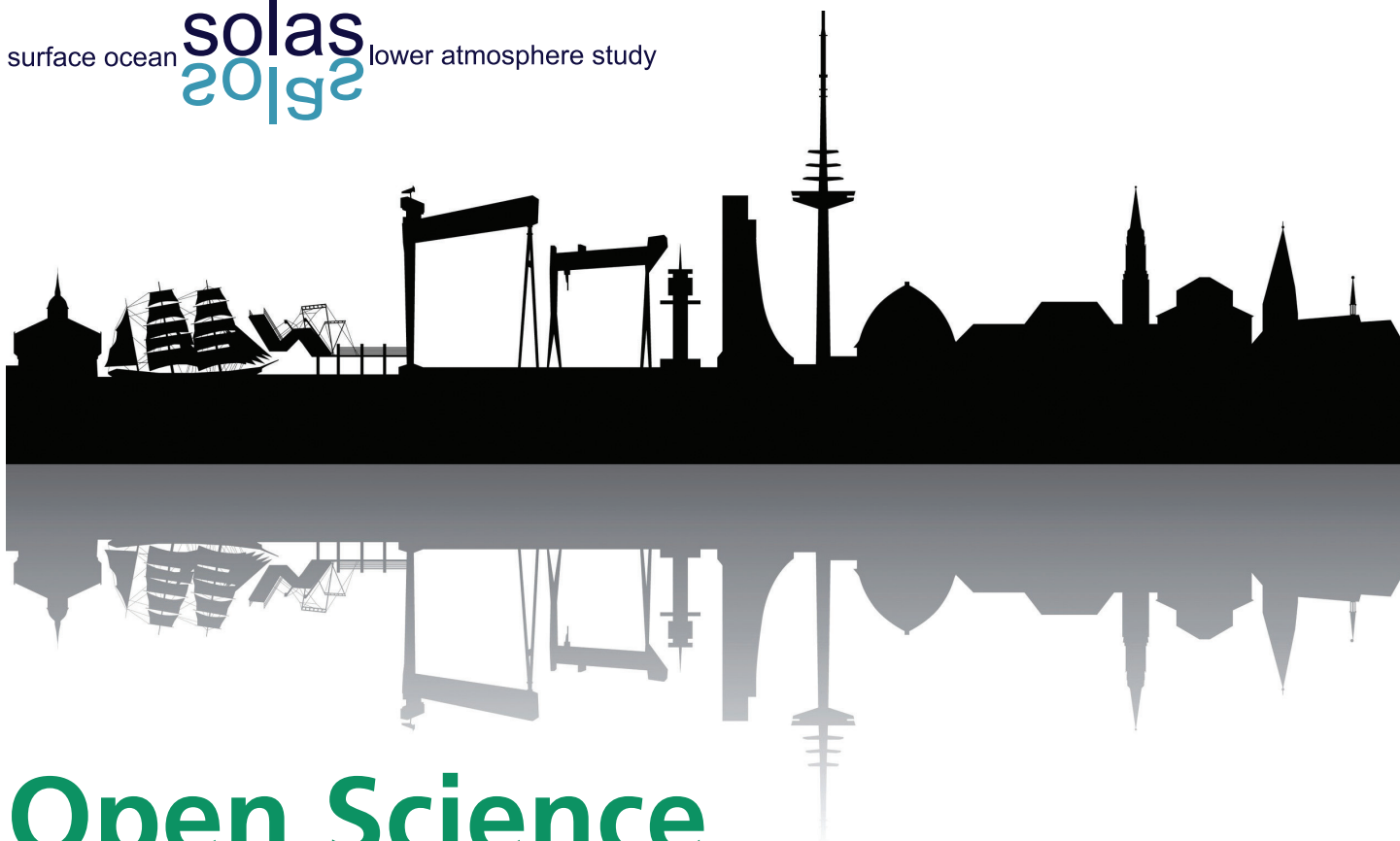
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